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TRENCHING AND SUBSOILING

FOR

AMERICAN VINES.

Compiled and Translated from European Authorities by

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TRANSLATORS' PREFACE.

In a retrospective survey of the early history of the reconstitution of French phylloxera-devastated vineyards on American resistant stocks, no feature is more conspicuous than the numerous disastrous failures recorded. These failures arose from very varied causes, among others, almost complete ignorance as to the classes of soil in which the American vines grew naturally, want of practical information with regard to their grafting affinity with European vines, uncertainty in respect to the varieties and even species planted, their doubtful resistance and occasional negative immunity to strong attacks of phylloxera, and, finally, adherence to the old methods of shallow preparatory cultivation in creating the new vineyards.

It is well known that these first failures of some 30 years ago in France, caused very heavy financial losses to viticulturists, but, their secondary effect amply compensated the losses, for thorough studies were forced to be undertaken on exact lines to ascertain the causes of the failures, and, the true explanations being arrived at, vine-growers, wary of the former object lesson and benefited by increased knowledge, were able to triumph over every obstacle, and eventually reconstitute their vineyards under extremely varied conditions, with the fullest measure of permanence, and success.

The primary object of the present compilation is to place before those Victorian vine-growers, who have been so unfortunate as to find their vineyards already destroyed, through the irresistible progress of the phylloxera, detailed descriptions of the practical working methods and implements now

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used in Europe, for overcoming one of the causes responsible in no small measure for numerous former failures in reconstitution with American vines, namely, ignoring the necessity for preparatory deep cultivation before planting out. At the same time, those growers not yet invaded would do well to prepare for the inevitable, as, ultimately, judging by European experience, the infection and destruction of all our vineyards by the phylloxera may be accepted as a certainty, being simply a question of time; every vine-grower, therefore, should feel compelled to study the ways and means for permanent reconstitution.

The practical experience of European viticulturists proves incontestably, that successful reconstitution on American vines, necessitates far deeper preliminary disturbance of the soil than that required ordinarily by European vines,* owing partly to radical differences in their root structure and underground development, but, principally, to the fact that phylloxera living on them is only prevented from inflicting serious harm through their more or less resistant and luxuriant root growth. This shows how essential thorough and deep preparatory cultivation of the ground is, in order that the recuperative root system may freely expand, without check or hindrance, so as to obtain the utmost benefit from the resistant stock, and enable it to increase in diameter at the same rate as the scion, for it is well known that most American stock actually used for reconstitution do not develop in diameter at the same rate as the *Vitis Vinifera* scion, without this essential preliminary of deep cultivation. This is now so definitely accepted throughout

* The advantages of deep cultivation, in the case of V. Vinifera, was recognised by the ancients. In the works of the Roman philosopher, Columella, *Rei Rusticæ Scriptores*, written early in the first century, during the reign of the Emperor Claudius I., the following very clear and precise passage on trenching occurs in Lib. III., sec. XIII.: "The soil of the plains should be disturbed to a depth of 1½ feet, hilly soils to a depth of 3 feet, and steeper hills to a depth of 4 feet, for, if the bed of soil ploughed with the *pastinum* is not made much deeper than is usually done on flat lands, the soil falling down from the top towards the bottom would leave a quantity of arable ground barely sufficient to allow it to be ploughed with the *pastinum*."

European vine-growing countries that it would be exceedingly unwise, and undoubtedly financially disastrous, to disregard this first essential condition, *i.e.*, *preparatory deep cultivation*, if we desire to assure the success and permanence of reconstituted vineyards in Victoria.

We do not consider it necessary to quote extensively from European authorities in support of this well-established and incontrovertible fact, but the opinion of Professor Pierre Viala, Inspector-General of Viticulture for France, and L. Ravaz, Professor of Viticulture at the National School of Agriculture, Montpellier,* as given in their work on American vines, may be accepted as unquestionably authoritative and representative; it is based on extensive practical experience and scientific study of the question, for principally under Professor Viala's direction, France has permanently reconstituted nearly 2,000,000 acres of phylloxera-devastated vineyards, embracing almost every class of soil :—

"*Deep Cultivation.*—The vine, like all plants, prefers a deeply loosened soil. Trenching or subsoiling is therefore necessary, and, if not indispensable (for all American vines can grow in untrenched ground), is at least of great utility for such varieties as the Riparia, most of the Rupestris, &c., which grow very slowly in compact soils. Trenching or subsoiling, however, obtains in many vine-growing regions for the varieties of the V. Vinifera, and in many places not a single vine is planted without previously trenching or subsoiling the ground to a depth of 20 inches, or even 3 feet.

"The vine grows more vigorously during the first years in trenched ground, and bears fruit at the third leaf, while in non-trenched ground it does not bear crops till the fifth or sixth year ; an advantage of two or three good crops is thus

* Viala and Ravaz. *Les Vignes Américaines, Adaptation, Culture, Greffage, Pepinières.* 2nd ed. Paris, 1896.

derived. It is always important to gather a crop as soon as possible, to cover the considerable expenses incurred in planting a vineyard; trenching, therefore, is more than ever necessary; it hastens the growth of the vine, and places it in better conditions for its future development.

"It is especially necessary for grafted rootlings. These young plants, often weakly at the time of planting, and with a root system always weaker than that of ordinary rootlings, usually remain sickly when planted in soils which are not favorable; thorough trenching greatly facilitates their early growth.

"Generally, trenching to a depth of about 20 inches is sufficient for American vines; a greater depth, however, suits them better. It may be done either by hand or plough. If in both cases the soil is not very calcareous, the subsoil should be brought to the surface, where it improves by contact with the air and under the action of successive manurings, thus augmenting the layer of arable soil. Further, as this is devoid of grass seeds, the vineyard may be easily kept free from weeds for several years.

"On the other hand, in calcareous soils, or when the subsoil is very calcareous, the latter must not be brought to the surface, or even mixed with the arable soil. We all know that carbonate of lime is detrimental to the vine, consequently, it is useless to mix it with the arable clay-siliceous or other soils in which the roots grow well, or even to place it on the surface, where the rain would carry it to the roots. Such a trenching would cause the leaves to turn yellow, and consequently prove its harmful effect. It is better in such cases to *subsoil*.

"Trenching, or subsoiling, under suitable conditions frequently removes the excess of water from damp soils, diminishes their coldness, and renders assimilable the matters which otherwise could not have been utilized by the vines."

More recently, Professor G. Foëx, Director of the National School of Agriculture, Montpellier, has expressed the following decisive opinions* :—

"Soils in which American vines are to be planted must be prepared with great care. From the different facts already mentioned in this book it results that with regard to adaptation to soil the greatest obstacle is, on the one hand, excessive moisture in winter and the cooling of the soil resulting from it, and on the other hand considerable loss of water through evaporation in dry summers. The best and only remedy for these two inconveniences is deep and thorough trenching. As a matter of fact, if the excess of water percolates easily through well-divided soil, it also remains longer under these circumstances, for the capillary attraction drawing it towards the surface where it evaporates is less felt than in compact soils. Finally the roots penetrate deeper and find better surroundings in soils deeply disturbed.

"*Depth of Trenching.*—Trenching previous to planting is therefore essential, but the depth of this cultural operation naturally varies with the nature of the soil. Soils naturally dry and poor must be disturbed deeper than fresh and fertile soils. In the first case the depth should be 24 inches, while in the second 16 or 20 inches might be sufficient. However, if the arable soil is shallow and rests on permeable limestone subsoil the latter should not be disturbed, for the roots can naturally penetrate it and get sheltered against drought.

"*Trenching must be done much deeper when a new vineyard is planted on the site of the old vineyard immediately after it has been uprooted. This is generally the case with American vines. Under these circumstances, a depth of* 30 *to* 32 *inches is required.*"

It has been urged against the hard-earned and costly experience of European viticulturists, which prove the impossibility of permanent reconstitution without previous deep

* G. Foëx, *Manuel Pratique de Viticulture pour la reconstitution des Vignobles meridionaux.* 6th ed. Montpellier, 1899.

cultivation, that those requirements do not apply to Victorian vineyards, the assertion most frequently advanced being that our vineyard soils do not require such deep cultivation as is necessitated in Europe for reconstitution. In other words, that our vineyard soils are naturally better suited to the vine without deep cultivation than those of France, Germany, Austria-Hungary, Switzerland,* Italy, Roumania,† and other European countries, where deep cultivation is accepted as an essential preliminary in planting American vines, and, therefore, that our usual procedure of shallow cultivation is ample. We have no hesitation in condemning this fallacy, as the assertion does not tally with the poor average yield of Victorian vineyards, or with the frequent occurrence of *pourridié* (a cryptogamic disease, attacking both European and American vines, for which no direct remedy is known at present).

Other viticultural countries, besides European, have blundered over the preliminary preparation of the ground for American stocks, notably California, in quite recent years, where vine-growers confidently ignored previous European experience. We would do well to profit by the Californian failures. Judging by some of the opinions expressed adverse to deep cultivation for American vines the exercise of a little discretion and common sense will save some of our local vine-growers, about to reconstitute, from a repetition of

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* The reconstitution of vineyards in Switzerland with American stocks was sanctioned by the Swiss Government in 1896 (*Rapport de la Commission administrative sur l'exercice 1895. Neuchâtel*, 1896), in consequence of the very limited success of the costly annual treatments involved in the attempts at extinction of the phylloxera.

The first Swiss State nursery of American vines was established at Auvernier as far back as 1889. There are now State nurseries for the propagation of American stock in almost every canton. These nurseries occupy over 15 acres. The area of Swiss reconstituted vineyards is increasing rapidly every year. (J. Dufour, *Les Vignes Américaines et la Situation Phylloxérique dans le Canton de Vaud.* Lausanne, 1899.)

† G. N. Nicoleanu, *La lutte contre le phylloxéra en Romanie.* Bucarest. 1905.

the disasters recorded by A. P. Hayne, Director of Viticulture for California.* We extract the following from Hayne's work on Resistant Vines:—

"*Cause of Failures.*—Another cause of failure in soils that to all appearances are 'Riparia soils,' is that the land was not in proper condition when the stocks were planted. It has already been remarked that the resistant vines require far greater care in planting than is usually given to the Vinifera. The most important point is the proper preparation of the soil before planting. It has been established beyond the possibility of rational doubt that, before planting American vines, the land should be given one ploughing that is twice as deep as would have been necessary had Viniferas been planted in the usual manner. This is one of the practical lessons learned abroad. One of the vineyards that is used by the Professors of the National School of Agriculture in France as the most striking illustration of the necessity of deep planting, is situated on the banks of the River Hérault, on the very best "Riparia soil" in France. When first planted in resistant stocks no deeper ploughing than had been given for the Viniferas was thought necessary. A very large vineyard was planted with Riparias. After several years it was found that they seemed to be total failures. As the soil was a typical Riparia soil, and the variety used was the very best, much interest was aroused. After consultation it was decided to dig out the entire vineyard, give it a very deep ploughing, and replant it with cuttings from the same mother vines that had supplied the cuttings for the original plantation. This was done, and to-day there is not a finer vineyard in the district. Experience has shown that all American resistants require deep ploughing at first, though some do not require quite as deep preparation as others. The Riparias are the most exacting in this respect. It is a safe rule to follow, that the drier and

* A. P. Hayne, *Resistant Vines: their Selection, Adaptation, and Grafting.* University of California, Sacramento, 1897.

poorer the soil the greater the care should be taken to prepare it for the reception of American resistant vines.

"*Preparation of the Ground.*—Here, again, attention must be called to a fact that has been well established the world over, namely, that all American vines must have deeper and better cultivation in starting than the Vitis Vinifera or European vine. This is not a theory, but a fact too well established under the greatest variety of conditions to be controverted. There are in this state some striking examples of the good effect of extra-deep ploughing before planting out American vines.

"Too great stress cannot be laid on this necessity of deep preparatory ploughing. Especially is this necessary in California on lands that, while not being especially dry, are apt to dry down considerably in summer. It is especially necessary with the Riparias and those resistant vines that tend to throw out their roots horizontally, instead of downward, as in the case of the Rupestris. But even the Rupestris requires deep ploughing to give it a good start. Professor Viala says that very deep ploughing of land destined to be planted in American vines will advance crop-bearing from one to two years ; and the facts certainly bear out this statement. Those who cannot give their vineyard land a ploughing twice as deep as is usually given, no matter what be the fertility of the soil, are advised not to plant American vines, for they will surely lose the money invested.

"The soil should be ploughed at least once, with a four-horse sulky plough, as deep as the plough can be driven—even if a couple of extra horses have to be called in to pull it. It is, of course, an expensive operation, but it pays, and pays well, to incur it. As before remarked, land thus prepared will yield paying crops two years sooner than if the ordinary method of ploughing be pursued, besides avoiding the risk of the loss of the entire vineyard. The poorer the

land the deeper it should be ploughed, and the more compact the land the deeper it should be ploughed."

According to F. T. Bioletti, of the Viticultural Department, University of California,* "In some of the loose, deep, rich soils of California, such deep subsoiling as recommended by Viala is unnecessary. In other soils, however, it has been found very advantageous to subsoil deeply, especially in somewhat exhausted land, or that in which a "plough-sole" has been formed by years of shallow ploughing. There are very few cases in California where deep subsoiling is a disadvantage, as our top soils are, as a rule, fairly deep. In some soils, however, which are very stony, deep subsoiling is impracticable, and in other soils where a stiff, raw clay is but a short distance from the surface it may sometimes be harmful."

There is another important feature in deep cultivation of vineyards, namely, the removal of stagnant or excessive water, as well as the roots of Eucalypts, &c., which are generally left to decay *in situ*. When an excess of water is present in a soil, the internal channels being choked, prevent the access of the necessary amount of oxygen, on which the activity of the soil, considered as a laboratory for the elaboration of plant food largely depends. Again, when trees have been badly grubbed, and roots left in the soil,† the mycelium of different fungi [*Dermatophora necatrix* (R. Hartig.), *Agaricus melleus* (L.) or *Armillaria Mellea* (Vahl.), *Rœsleria hypogœa* (Thum. and Pass.)] develop rapidly, especially in

* Communicated to us. September, 1900 [R. Dubois].

† Palladius (370, 395 A.D.), a Latin author, describes trenching in his work on Agriculture, Book II., section X, and refers to the removal of roots. "The time has now arrived for working the land intended for vines with the *pastinum*. This may be done in different ways, by disturbing the whole surface, by making trenches, or by forming pits. The soil should be wholly turned over, *so as to remove stumps, roots of ferns, and other detrimental plants.*" Palladius was a noted plagiarist; it is supposed that his agricultural methods were largely borrowed from Magon, of Carthage, who wrote an Encyclopædia of Agriculture in 22 volumes, 540 B.C. When Carthage was conquered by the Romans, the Roman senate ordered this great rural encyclopædia to be translated for the benefit of Roman agriculturists.

damp clayey or marly soils with an impermeable subsoil. This fungus growth soon gains the roots of vines, developing on them, and occasioning a disease known as *pourridié*. The effects of this disease are as disastrous as those of phylloxera, for it finally results, in soils favorable to its development, in the death of the vine attacked. It accounts in a measure for the small yield of Victorian as compared with reconstituted deeply-cultivated European vineyards. As we have already remarked, no specific remedy or treatment for it is known. Probably many vine-growers are familiar with this disease, as its white mycelium filaments are easily detected by the eye, and are readily distinguishable by their decided mushroom odour. It exists in a more or less acute form in almost all the vine-growing districts of Victoria. Its appearance can only be attributed to excess of water in the soil, together with old decaying roots in the subsoil. This has been very clearly proved by investigations made by Rochemache* in connexion with the cause of failures in vineyards planted in cleared ground, trenched to a depth of 16 inches; the trenching had not been deep enough to remove all roots, which, consequently, acted as sources of the fungi from which the contagion originated, and, in conjunction with stagnant water, formed veritable hot-beds of infection by *pourridié*.

To sum up, it is an essential condition, if we desire to insure permanence and success with American stocks, to disturb the soil deeply, for the following reasons :—

1st. To enable their root system to expand freely, in order to assure the stock developing at the same rate as the scion, and, consequently, success in grafting and profitable yield.

2nd. To allow access of air to the subsoil, chemically essential to the elaboration of the substances necessary for the nutrition of vines.

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* *Revue de Viticulture*, 1899.

3rd. To remove stagnant or excessive water.

4th. To extract all roots. The two latter conditions being imperative to prevent the appearance of *pourridié*, and therefore a diminution in the grape yield.

The principal local objections urged against preparatory deep cultivation are :—

1st. The proper implements and knowledge of methods are not obtainable in Victoria.

2nd. The work is too expensive.

The object of the present compilation is to answer the first of these objections, by describing in detail the methods, machinery, and implements used in European vine-growing countries, giving their cost when available ; and to show that deep cultivation is possible by using large heavy ploughs hauled by winding-drums worked either by horse or steam power.

In answer to the second objection we urge co-operation in the purchase of the necessary machinery or implements. If a few neighbouring vine-growers unite and purchase these in common, the outlay will be divided between several persons, and, as the operations will extend over a greater number of days per year, the cost of cultivation will be reduced proportionately, and will not be found to exceed that now paid for ploughing 12 or 14 inches deep. Further, when the trenching or subsoiling operation is finished, the plant may be used for ordinary ploughing, harrowing, scarifying, rolling of vineyards, as pointed out by A. Debains (see page 135).

In conclusion, we quote the pregnant words of Professor B. Chauzit*—

" Great importance must be attached to the trenching or subsoiling of vineyards; the future of the vine is entirely dependent on this operation. Reconstitution on American

* *Revue de Viticulture*, 21st October, 1899.

stock becomes rapid, the vines bear heavily and much earlier in well-trenched ground, on the contrary, in shallow trenched ground of from 10 to 14 inches, for instance, American vines develop very slowly and are unproductive. We cannot therefore take too great care in the thorough performance of trenching. It is the basis of the successful establishment of a vineyard. If in the beginning expenses are curtailed, the future of the vineyard is compromised. To economize in deep cultivation is to forestall failure before having even started the viticultural work on which one depends."

RAYMOND DUBOIS.
W. PERCY WILKINSON.

Viticultural Station,
Rutherglen, November, 1900.

I.

TRENCHING AND SUBSOILING FOR AMERICAN VINES.*

By P. Ferrouillat,
Director of the National School of Agriculture, Montpellier.

WHIM, OR HORSE-GIN.

Under the name of *whim*, *horse-gin*, or *winding drum*,† we understand a simple machine frequently used to overcome a great *resistance* with a very small *motive power*. Fig. 1 is a *windlass* commonly used for raising water from a well. It consists of a drum or cylinder A A′ of wood or metal, at both extremities of which are axle-trees

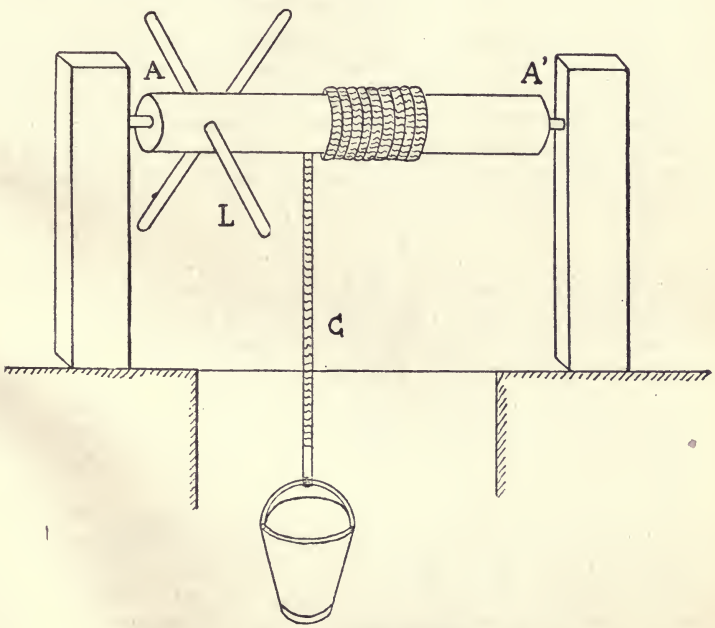

Fig. 1.—Ordinary Windlass.

* *Le Progrès Agricole et Viticole.* Vol. 15. 1891.

† These words are used as equivalent to the French "*treuil.*" Horse-gin, according to Webster's Dictionary, 1899, is a contraction of horse-engine. (Trans.)

revolving in two sockets. Levers L are fixed through the cylinder, and it is by acting on these levers that *power* is applied.

A rope or cable C wound on the drum, supports a bucket, the weight of which is the *resistance* to be overcome. The friction of the axle-trees and the rigidity of the rope not being taken into consideration,

P, being the effort exerted tangentially at the extremity of the lever L.

l, the length of the lever, measured from the axis of the cylinder.

Q, the weight to be raised, or the *resistance*.

r, the radius of the cylinder around which the rope is wound; it is shown in mechanics that—

$$\frac{P}{Q} = \frac{r}{l}, \text{ or } P = Q \times \frac{r}{l};$$

that is to say, that the motive power is to the resistance as the radius of the cylinder is to the length of the lever, or, in other words, that the motive power is a fraction of the resistance equal to the ratio between the radius of the cylinder and the length of the lever. The smaller r is in relation to to l, the greater Q may be in relation to P. If for instance,

$$\frac{r}{l} = \frac{1}{10},$$

we may, with an effort of 10 lbs. raise a weight of 100 lbs. Practically, we must take into account the friction of the axle-trees and the rigidity of the rope, so that the useful resistance Q′ overcome by the windlass, is a little less than Q, which, theoretically, is in *equilibrium* with P. We will see the importance of these *passive resistances*, also called *detrimental forces*, in the machines we are going to study.

In mechanics *we always lose in velocity what is gained in force*, and reciprocally. If the windlass equilibrates a great resistance by a small motive power, it is only at the expense of the velocity or rate. We see that the path traversed at each revolution of the windlass by the moving power is equal to $2 \pi l$; that traversed by the resistance is $2 \pi r$. These two paths traversed in the same lapse of time are, therefore, in inverse ratio of the effort developed to the resistance overcome. We may, with a moving force of 10 lbs. raise 100 lbs., provided r be $\frac{1}{10}$ of l, but the weight,

Q, will travel ten times slower than if the force P, was applied directly with the same velocity; or, what is the same, it will take ten times longer to raise the weight.

The windlass arranged as shown in Fig. 1 may also serve to raise loads. It forms the essential part of the machine known as the *lifting crab*, which is used in building to raise stones and timbers. The lever *l* may be replaced by a winch-handle made fast to one of the axle-trees passing through a socket. In the quarry windlass a large wheel of 13 to 19 feet in diameter replaces the levers. It is provided with bars. Men mount these bars as if on a ladder, and it is their weight which constitutes the moving power.

If the axis of the windlass is vertical instead of horizontal, and if, therefore, the levers rotate in a horizontal plane, the machine takes the name of *capstan*. The conditions of equilibrium are evidently the same. Under this form the capstan is sometimes used in cellars to work wine-presses; the rope is fixed on the bar of the press, and men work the winding drum of the capstan with capstan bars.

To attain still greater traction, toothed wheel gearing may be interposed between the motive power and the resistance. Fig. 2 shows diagrammatically the toothed-wheel gearing. The drum *t* carries a toothed wheel R′ geared with a pinion *r′*. On the shaft of this pinion a toothed wheel R is fixed gearing with a pinion *r*, on the shaft of

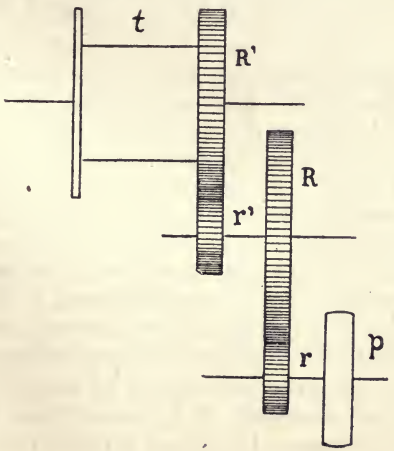

Fig. 2. – Toothed-wheel gearing.

which the transmission pulley is fixed, connected by a belt to a horse-gin or portable engine. If an effort P is applied on the pulley p, the pinion r will revolve the wheel R, the pinion r will revolve the wheel R′ and the drum t, and if a rope is coiled on the drum at the extremity of which is a resistance Q, in the form of a load to be hauled, the load will gradually move towards the machine. Disregarding frictional losses and the rigidity of the rope,

l, being the radius of the pulley;
a, the radius of the drum;
R, R′, r, r', the radii of the toothed wheels, or the number of their teeth; we have, theoretically—

$$\frac{P}{Q} = \frac{r\ r'\ a}{R\ R'\ l'} \text{ or } P = Q \times \frac{r\ r'\ a}{R\ R'\ l}$$

As a r' r are always very small compared to R R′ and l, P is very small compared to Q, we can, with the toothed wheel gearing train, overcome considerable resistances, which, with the simple capstan, would have been impossible. But we must not forget that this gain in power, and consequently diminution of velocity, corresponds to a loss of time so much the greater as the gain in itself is higher.

It is surprising to notice that the wheel-and-axle principle so extensively applied for a long time in other industries, and constructed under so many different forms and dimensions, has been so tardily applied for the draught of agricultural implements.

Deforges, constructing engineer, in an interesting report, after a special competitive show of horse-gins and winding drums held at Narbonne in 1888, relates that before 1815 an old sailor in the Département of the Pyrénées established a capstan at the end of a small field, by means of which he hauled his plough, and consequently cultivated his land. In the same report, Aubert, a land-owner, in the Département of Basses-Alpes, is also mentioned as having used a capstan for hauling his ploughs in 1834. But these isolated trials remained for very many years without creating a movement in favour of these devices.

Nothing less than the destruction of vines by phylloxera and the general necessity of reconstituting the different vineyards was necessary to compel attention to the merits of these machines.

Deep cultivation, such as is now actually done, is almost impracticable with bullock or horse teams, whatever be the number of animals. In the first instance, the farmer must possess enough animals, and only a few can spare fourteen or sixteen draught animals; and what is more, when more than ten or twelve horses work together, their power is very badly utilized, as each animal does not furnish the power it is capable of yielding when alone, and a moment comes when nothing is gained by adding another animal. This loss of power is more noticeable with horses, as they get nervous, and with which it is difficult to obtain regular traction. Finally, in the management of a large team, the starts and turns are extremely difficult. Therefore, the execution of this work has only been possible so far with a steam plant. The Fowler system is the only one that has hitherto been available to viticulturists; however, its use is not without drawbacks. Its high cost and expensive attendance preclude it from the reach of vinegrowers, who, as a rule, only hire it. In this case it is often difficult to get it at the fixed date for a contract time for small surfaces to be ploughed, etc. The travelling on roads or over culverts of these powerful locomotives used for driving heavy ploughs has grave inconveniences. It was, therefore, indispensable to devise a new machine to replace the expensive and cumbersome material used in Fowler's steam ploughing, and place within the reach of all small, medium, and large growers the means for trenching or subsoiling their ground. In 1876 Grué, a vinegrower at Solliès-Pont (Var), first applied the capstan as a mode of traction for trenching or subsoiling ploughs. It is easy to imagine a plough secured at the end of a steel wire cable, winding round the drum of a capstan, and two horses yoked at the extremity of the bars of the capstan, to understand that these animals will put the plough in motion. If the drum has a radius of 19 inches, and if the bars have a length of 16½ feet, the two horses will do the work of a team of twenty applied directly to the plough. But the plough will travel ten times slower. This question of speed and time is, however, generally of secondary consideration, as the capstan allows the grower to plough to depths which he could not reach without using steam, even if he had twenty horses at his disposal, and such a team could not be practically managed.

The purchase of a great number of horses for work of short duration has this double disadvantage, that, firstly, they could not be sold again without a loss ; and, secondly, the inclemency of the weather may interrupt the work, in which case the horses are fed without being utilized. With a horse-gin one may, without increasing the staff and teams, perform better work than would be the result if direct draught were used.

Grué's idea, although so simple and practical, was not immediately adopted by agriculturists, and the gin adapted to the traction of ploughs by horses, or oxen, did not come into general use as rapidly as might have been hoped, considering the requirements of viticulturists. Ten years elapsed before the gin conquered at last, and gained the confidence of all.

In the meantime, Bourguignon, who constructed the first machines for Grué, made a certain number of other gins, particularly the Valessie gin. But it is to Beauquesne, of the Ecole Polytechnique, that the honour is due of having, thanks to a profound conviction and obstinate persistence, forced agriculturists to adopt these machines.

Although the Beauquesne gin is an enormous advance on the machines constructed previously, it is not without several defects. The ingenuity of constructors was awakened by the success of these machines, and did not take long in triumphing over the difficulties which their application presented in practice, and the last show of gins, which was held in the spring of 1890, proved that the gin had at last become an implement of great perfection.

While this transformation was taking place, Grué on one side, Beauquesne on the other, were trying to apply the capstan system to the utilization of portable engines for the draught or traction of ploughs. As the horse-gin allows viticulturists to do with two horses cultivation which would require twenty in the ordinary manner, the steam winding drum gives, in the same way, the means to do with a small portable 6 H.P. engine, work which formerly required powerful winding drums of the Fowler system. The steam winding drum is nothing less than a toothed wheel gearing train, the pulley of which is connected with the belt of the engine. Although the principle of this machine seems very simple, it had to be devised so as to render the winding drum

practical. The Perpignan show enabled us to appreciate the progress accomplished in this direction; and, even if some modifications of detail yet remain to be made, viticulturists have already at their disposal new machines of great power and of incontrovertible utility.

There are two classes of trenching or subsoiling capstans:—1st, the horse-gin, for use by the medium grower; 2nd, the steam-winding drum, for properties possessing a portable engine. The machines of the latter class may be used for small properties, through contractors undertaking the work. The trenching or subsoiling per acre with this contrivance is generally less expensive than with Fowler's machines, on account of the considerable difference in the prices of the plants.

Horse-gins or Whims.

Horse-gins are divided into:—1st, fixed gins; 2nd, movable gins. While the former are established in a fixed position of the field to be trenched or subsoiled, and are fixed during the whole time of the duration of the work, the latter are arranged on one side of the plot to be ploughed, and are displaced in front of every furrow, travelling from one extremity of the field to the other. In the first class may be grouped the Beauquesne and Musquère systems; in the second, all other systems.

Beauquesne's Horse-gin.

Although the Beauquesne machine is not the first that was used for deep cultivation, it is certainly the best known. It was first used in 1887. Since that date it has been improved in details, but as a whole has remained as it was when first brought out, remarkable for its great simplicity and rusticity.

Description.—The complete machine is composed of three essential parts—A *capstan*, *cable*, and *fixed pulley*.

The capstan consists (Fig. 3) of a drum C, the diameter of which may vary between 27½ inches and 4ft. 3in., around which the cable is wound. This drum runs loose on the vertical shaft, which is strongly fixed to a cast-iron cross bolted on a wooden base frame, formed of two beams 9ft. 9in. in length. A coupling clutch P, running loose on the same shaft carries the pole B. The throwing-into-gear lever L, allows the raising or lowering of the clutch P. When raised it is independent of the drum C. When

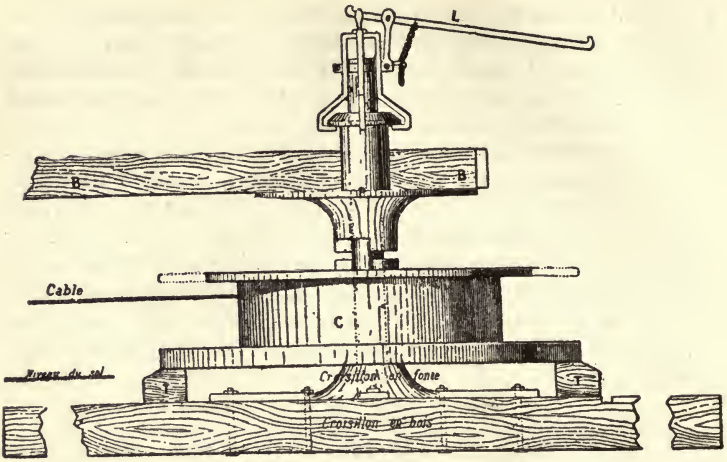

Fig. 3.—Beauquesne's Horse-gin.

lowered, on the contrary, it throws the drum into gear, and the horses yoked to the pole B, in their circular motion wind the cable on the drum. The machine increases the draught ten times.

The cable is made of steel wire. It is about 274 yards long, and generally 0·51 to 0·55 inch in diameter.

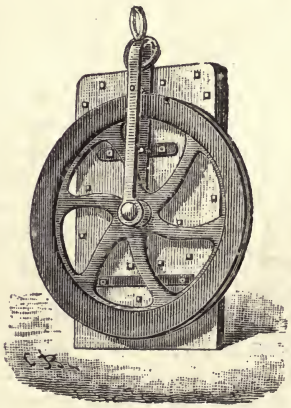

Fig. 4.—Fixed Pulley.

The fixed pulley is a shive supported by a wooden framework, through which passes the axle (Fig. 4). A length of chain, ended by a large link, allows the frame to be fixed to another chain, the extremities of which are secured to two anchors deeply buried in the ground. By this process the pulley may easily be displaced on the ground, by allowing the terminal link of the small chain to slide along the large one without removing the anchors.

Working.— Under one of the beams of the frame of the capstan, an axle is attached by which the machine is fixed on wheels, to facilitate travelling it from one place to another. Two excavations are made in the ground for the

wooden beams, the wheels are removed, the capstan placed in position in the excavation, and fixed by a few iron or wooden pegs. The gin is generally placed at one angle of the field to be ploughed (Fig. 5). After lifting the coupling clutch the cable is unwound and passed over the fixed pulley,

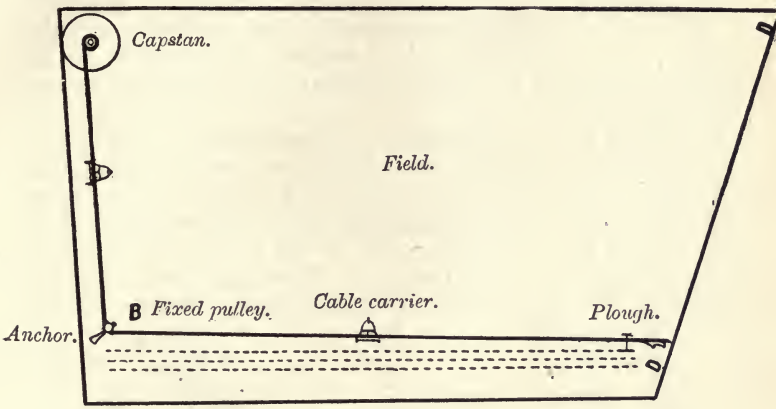

Fig. 5.—Arrangement of Capstan in the Field

which is anchored at the extremity of the first furrow to be turned by the plough, to which the free extremity of the cable is fixed. When the distance is considerable the cable is supported by cable carriers (a kind of small carriage provided with a ground pulley) to diminish the wear and tear (Fig. 6). At a distance of about 19 feet from the capstan a small device is placed for facilitating and regulating the winding of the cable on the drum. The horses are then harnessed to the pole, the machine thrown into gear, and all is ready for a start.

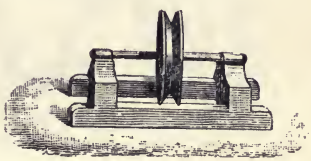

Fig. 6.—Cable carrier.

The installation is simple, and does not require much skill; the fixation of the anchors which hold the fixed pulley, alone presents some difficulty. It is necessary to prevent the enormous traction exerted on them from pulling them out of the ground. When the soil is naturally compact and resistant this need not be feared, but in swampy or light gravelly soils it is difficult to keep the anchors in

position. This accident is so frequent with the anchors that Beauquesne was forced to discard them and substitute anchoring plates, the resistance of which is much greater. These plates, formed of strong girders, lodged in trenches in the ground, and resting on an extended surface, support very considerable efforts without yielding. It is not rare, however, to see them pulled out of the ground in certain soils. It is preferable, when circumstances allow it, to anchor the pulley to a wall or trees ; even these are sometimes pulled out.

It should be noticed that the two anchoring points of the chain holding the pulley have to sustain unequal tractions, and that the pulling out of one end is more to be feared than the other. This is shown in Fig. 7 ; the traction T of the capstan and the resistance T′ of the plough give a resultant F applied to the point *d*. This resultant is equilibrated by the resistance R of the anchoring chain. If this

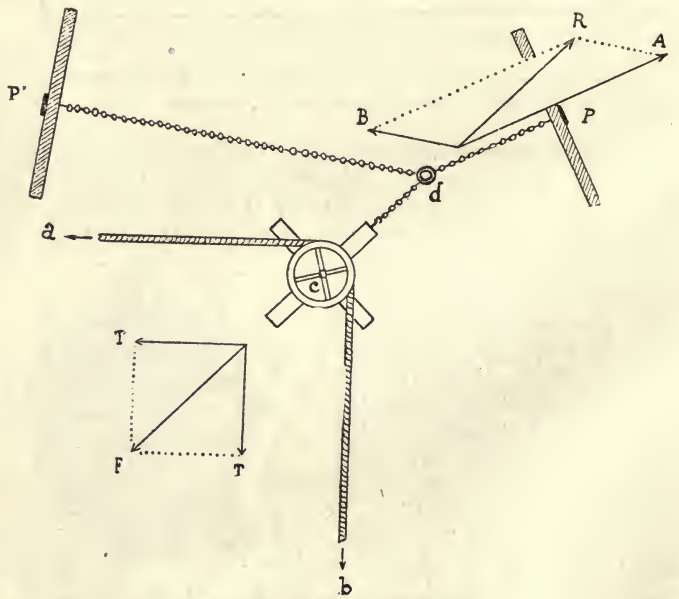

Fig. 7.— Anchoring of the Fixed Pulley.

resistance is resolved into its two components, A directed towards the anchor P, the other B directed toward the anchor P′, we see that the effort applied to the first anchor is greater

than that applied to the second, and greater than the traction of the capstan or the cable. In practice the anchor plate P gives way before P′, therefore the anchor plate P requires to be fixed more carefully. This is the greatest defect of the system.

The plough made on the Brabant system is of great power, all the parts being strengthened and strongly braced together. When the plough hauled by the cable reaches the fixed pulley, the plough is thrown out of gear, leans on the mould-board, and comes out of the furrow. The coupling clutch is thrown out of gear, the capstan stops revolving, and the plough is lifted up, placed on a small two-wheeled truck, and hauled by a horse to the starting point of the new furrow (Fig. 8). To regulate the unwinding of the cable, the driver acts on the

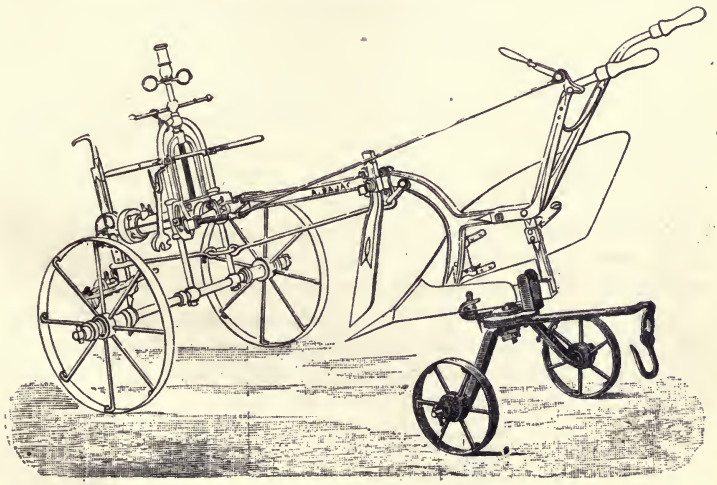

Fig. 8.—Plough ready to be hauled back.

drum with a wooden lever as a brake. While this is done the chain of the fixed pulley is shifted along the anchoring chain to a distance equalling the width of the furrow, so as to have the chain opposite the furrow to be opened, and the operation is again repeated.

If the field to be ploughed is too large to allow the work being done from one position of the capstan, without detrimentally increasing the length of the cable, it is partitioned in a series of rectangular blocks, the position of the capstan being changed as many times as there are rectangles. We

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may reduce the number of shiftings by placing the capstan in the middle of the plot, instead of a corner. In this case, with a cable 274 yards long, one may, without shifting the capstan, plough about 15 acres. At the end of the work non-ploughed headlands are left. On the side where the capstan and pulley are fixed the headland is 23 to 26 feet in width ; on the other side, about the length of a horse. The headlands are ploughed in the same way as above described, leaving only four small squares unploughed at each corner of the field.

The traction cable is not buried, and passes across the circular track made by the horses. They have to walk over it. They very quickly become accustomed to this, and the slow rate of the cable renders it very easy, the drum being level with the ground the height of the cable does not exceed 9 inches from the surface. This arrangement has been proved to be the most practicable and simple, and without danger to the horses.

Two objections may be raised against the Beauquesne system. The first is relative to the difficulty of anchoring the fixed pulley, the second relates to the shifting of the capstan from one place to another. Notwithstanding these objections, this horse-gin remains the most practical, and on account of its simplicity and strength it has and will still render great services to viticulturists. Its price is £48, including 220 yards of cable, plough excluded.

The plough used by Beauquesne is that made by Pol Fondeur, at Viry (Aisne) specially strengthened to resist the enormous effort it has to support (Fig. 9). It is a good

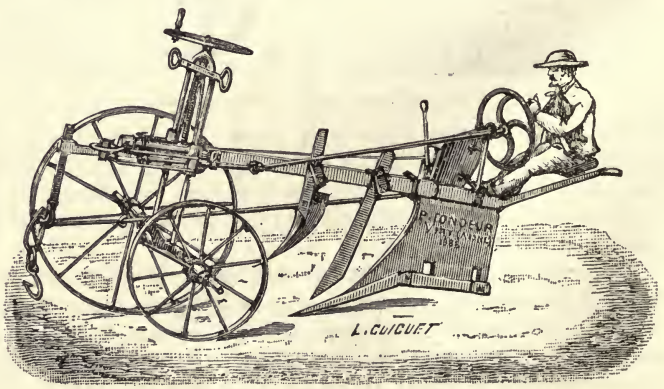

Fig. 9.—Pol Fondeur's Trenching Plough

implement. Only the fixing on the truck to bring it back to the beginning of the furrow is a rather troublesome and tedious operation. It is done as follows :—The beam of the plough carries a vertical shaft with a toothed rack, gearing with a pinion. Directly the plough has come out of the furrow leaning on the mould-board, or breast, it is lifted upright, a plank is placed under the vertical shaft, and, by means of a handle working the pinion the shaft is lowered. It rests on the plank lifting the body of the plough. The truck is slided under the frame and keyed on to it. The shaft is then raised and the plough resting on the truck is ready to be drawn back. This device is shown in Fig. 8.

Musquère's Horse-gin.

The horse-gin of Musquère, of Salses (Pyrénées-Orientales) presents some analogy to that of Beauquesne.

Description.—The frame of the capstan is made of rolled joist girders, braced with angle iron.

The winding drum is 3ft. 3in. in diameter, the pole 11 ft. in length. The ratio of the speeds $\frac{1}{68}$. Two poles may be fixed on the socket head. The device for throwing into gear resembles that of Beauquesne.

Working.—To instal the capstan a deep trench is dug to receive the wheels and frame. The machine is buried to the level of the bottom flange of the drum. The stability is great, but the fixing tedious. The cable passes over a fixed pulley made fast to a chain, the two extremities of which are anchored to a series of iron pegs arranged like a claw. The sliding of the pulley on the anchoring chain is done in the same way as with the Beauquesne plant.

The plough used is a Vernette trenching plough. To carry the plough back to the beginning of the new furrow, it is tilted over on two wheels.

This gin with 274 yards of cable costs £64.

Grué's Horse-gin.

Léonce Grué first attempted in 1876, on his farm at Beaulieu, Solliès-Pont (Var), to haul heavy trenching ploughs by means of a winding drum. The first machine was very imperfect, but the principle was good, and Grué had only to make a few modifications to create the horse-gin which now bears his name, and which is sometimes known under the name of Beaulieu gin.

Description.—It consists essentially of a horizontal winding drum (Fig. 10), made of sheet steel and angle iron.

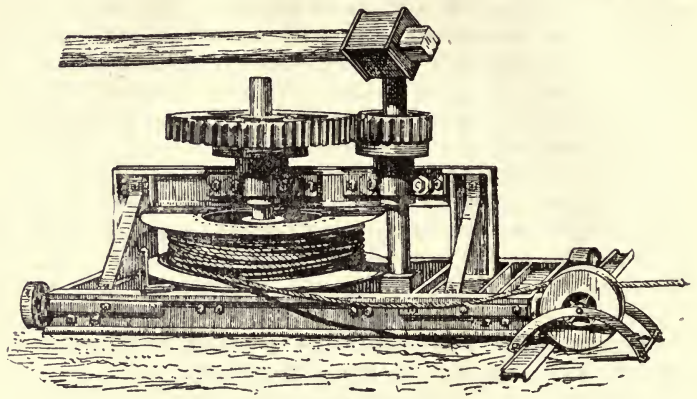

Fig. 10.—Grué's Horse-gin.

It is very strong, and is set in a frame made of iron rolled joist girders and T iron, easily dismounted by means of bolts. Above the frame a pair of cog-wheels are interposed between the pole axis and the drum axis, which according to their position, allow different rates of winding to be obtained, and consequently different powers of traction. A pole-socket fixed on one of the vertical shafts carries the pole, the frame rests on four rollers, rolling on two rolled joist girders, placed flat on the ground, and serving as rails.

This gin has three speeds. For very deep cultivation, requiring great traction, the large cog-wheel is keyed on the drum shaft, and the pole-socket keyed on the shaft of the small pinion. In this case the traction on the cable is to the power of the animals as 20 is to 1. For ploughing at a medium depth, the pole-socket is keyed directly on the drum shaft, working independently of the cog-wheels. In this case the effort is increased ten times, as in the Beauquesne machine. If the working of the land does not require so much power, one may work quicker by fixing the small pinion on the drum shaft, and the large cog-wheel on the shaft carrying the pole. The effort in this case is increased five times. The shifting of the cog-wheels is done very easily. They run loose on the shafts, and are engaged by means of a cotter fixing them to circular plates, placed underneath and keyed on the shaft.

Working.—The gin is installed on the shortest side of the block, and opposite the first furrow to be opened. It is carried by two rails fixed in the ground by means of pegs. The weight of the machine is sufficient to keep it in place. The cable is made fast to the plough, and acts directly without passing over a fixed pulley. This pulley would only be necessary in the case of a block of irregular shape, where the gin could not be easily brought opposite the furrows. The horses in their circular track haul the plough, which, when it reaches the machine, is tilted on its side, placed on a small truck, and carried back by a horse to begin another furrow. While the plough is being taken back the gin is moved forward a distance equal to the width of a furrow. When the machine reaches the end of the rails, a second pair of rails is placed in line ; when the machine is on these, the first pair is taken up and placed in line in their turn. Four rolled joist girders are therefore sufficient for travelling the gin along the headland. The machine travels by degrees from one end of the block to the other, leaving only two headlands unploughed. The headland on the gin side is about 40 feet wide, on the opposite side 11 feet.

The dispensing with the fixed pulley, and displacement of the gin on rails, are the characteristic and principal advantages of Grué's gin. This advantage is considerable, as the installation of the machine is much simplified ; for the doing away with the pulley avoids the difficulty of anchoring, which is an almost insurmountable difficulty in certain soils. Grué's machine for these reasons has had many imitators, and movable gins are nowadays mostly used. The contrivance allowing three different speeds to be obtained is not very useful. Increasing the motive power by ten is quite sufficient, as in this case two horses exert an effort equal to twenty yoked directly to the plough. By increasing this power at the expense of the speed the latter is too much reduced, and the daily work done by the plough becomes insignificant ; by diminishing it on the contrary the use of a winding drum is not justified, for its aim is simply to allow deep ploughing, impossible to be performed with ordinary teams. The cog-wheels of the Beaulieu gin could therefore be dispensed with, the socket head keyed directly on the shaft of the drum would greatly simplify the machine.

Its price without cable or plough is £64 ; without the cog-wheels it only costs £40.

The gin hauls a trenching plough, built specially for it by Durand, of Montereau (Seine-et-Marne). This implement (Fig. 11) is of very great power, and allows land to be ploughed easily to a depth of 2 feet. It has three coulters with a steel share, made in such a way as to keep the plough well into the ground. All the regulating may be done during work without stopping, by means of a hand-wheel acting on screws; a small wheel is fixed at the rear of the plough to take it back to new ground. This wheel revolves on a lever, at the extremity of which is a hook. During the ploughing the small wheel lifts automatically and revolves on the bottom of the furrow opened by the plough. To carry the plough, the swingle bar is secured to the hook of the lever; the traction of the horse lowers it, and at the same time forces the small wheel to rest on the ground, lifting the frame and allowing the plough to run on three wheels. This small wheel is articulated so as to form a fore-carriage replacing the truck. The plough weighs 13 cwt. 3 qr., and costs £38.

Grué's Double Winding-drum Gin.

Grué also makes a double winding-drum gin, allowing the plough to be worked both ways and avoiding the time lost in pulling the plough back to new ground.

Description.—This gin is composed of two drums, each winding a cable. One of these is fastened directly on the plough, the other one, which is longer, passes over a fixed pulley anchored on the opposite headland, and is then made fast to the plough; these two drums may at will run loose on their shafts or be keyed on to them. It is easy to understand that these two drums will alternately wind and unwind the cable, drawing the plough backwards and forwards, therefore the ploughing will take place both ways without loss of time. The plough in this case must evidently be either a turn-wrest plough or a balance plough, turning the sod on the same side during its passage both ways. (See Figs. 12 and 27.)

In this case the difficulties again reside in anchoring the pulley. Grué solved the difficulty in the following way:—Three iron beams, 10 feet in length, are placed one above the other with a space of 4 inches between each. Corresponding holes are punched out of each beam, and a spindle serving as axle to the pulley passed through

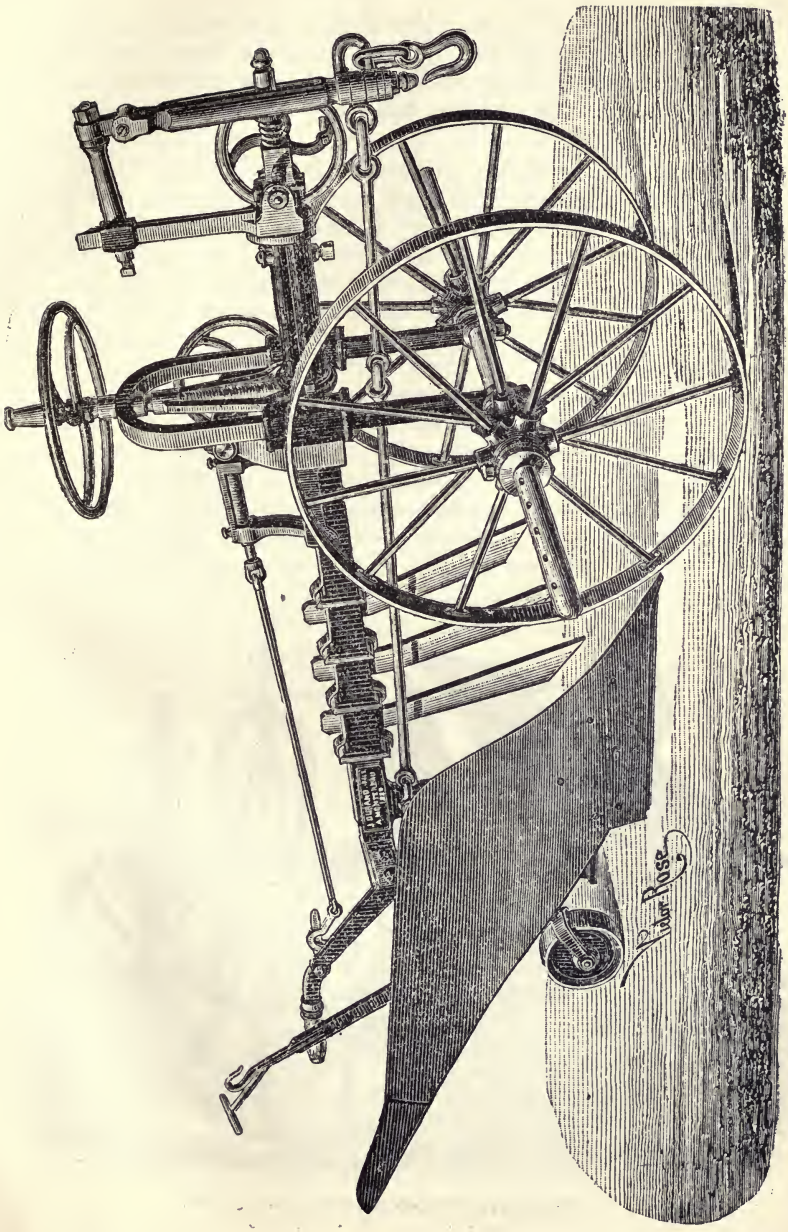

Fig. 11.—Durand's Trenching Plough.

them. To shift or displace the pulley at each furrow, the spindle is taken out and put in the next hole, and so on. The beams are kept in the ground by means of strong iron posts, and the device has only to be moved every 10 feet.

This method of fixing the pulley is not without drawbacks, and in pebbly, light, or boggy ground, the pulley rapidly drags the beams out. It has, as a matter of fact, to resist a traction double that resisted by the gin, as the two parts of the cable passing over the pulley are parallel, and the stress on each part is equal to the effort of traction exerted tangentially to the circumference of the drum. Notwithstanding Beauquesne's anchoring plates, the fixed pulley of his machine (the resistance of which does not require to be double that of the effort of the capstan) is often dislodged. We cannot, therefore, expect greater stability on the part of the fixed pulley of Grué's system. This compound machine, the main advantage of which seems to be the rapidity of execution of work, cannot in reality attain much greater rapidity, as the displacement of the pulley,

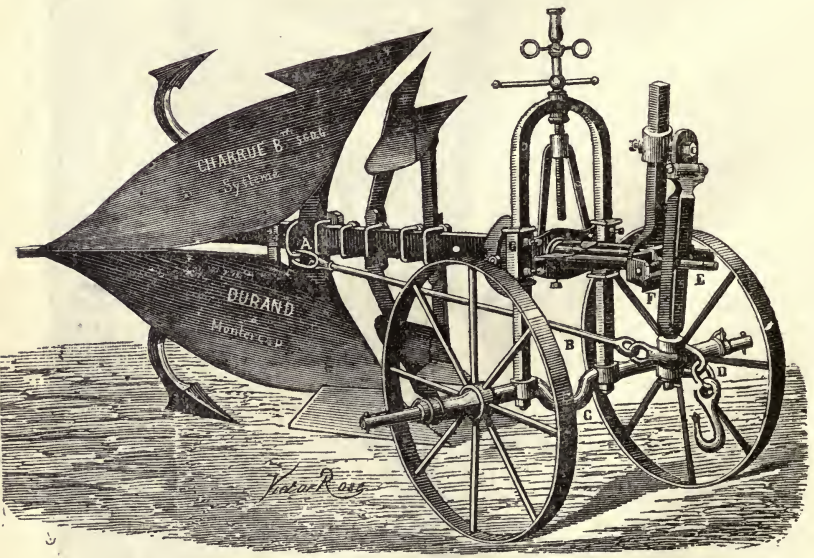

Fig. 12.—Durand's Turn-wrest Plough, with Subsoiling Tines.

the anchoring, the possible dislodgment, are so many drawbacks to the regular working. Its high price, £100, is, on the other hand, an obstacle to its use by small and medium growers. The turn-wrest plough, with a subsoiling tine (shown in Fig. 12), may be used with this capstan. In soils of medium stiffness, the trenching part of the plough works at a depth of 16 inches, the subsoiling share working 6 to 8 inches deeper, making the total depth of work 22 to 24 inches.

Durand's plough costs from £20 to £30.

Bourguignon's Horse-Gin.

Auguste Bourguignon, who first constructed the Grué gin, has, since 1887, built the Valessie gin.

Description.—This gin is composed of a cast-iron bed-plate, the dimensions of which have been calculated so as to enable it to be carried on an ordinary dray. This bed-plate rests on two long axles (Fig. 13) each bearing two rollers, rolling on angle irons bolted on wooden beams. On this bed-plate a frame-work or *bridge* is bolted, inside which the drum is placed, keyed on a vertical shaft, revolving on a bronze cup socket in the centre of the bed-plate, and through a collar in the upper part of the bridge. On the top of the shaft a circular plate is keyed, perforated with six holes at

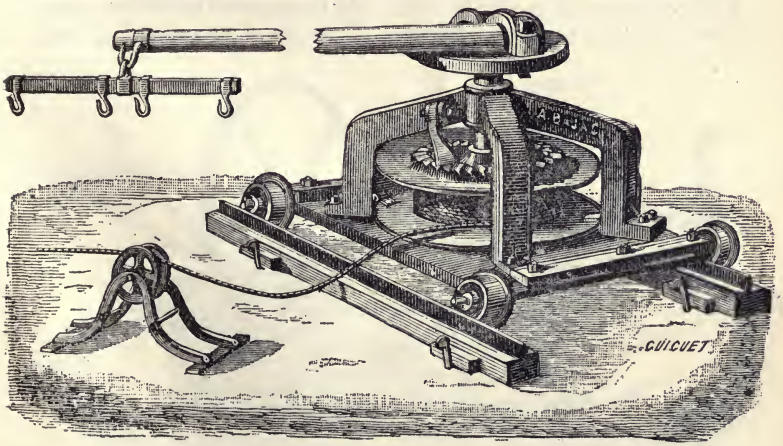

Fig. 13.—Bourguignon's Horse-gin.

the periphery, above it the pole socket-head runs loose on the shaft, but may be clamped to the plate by a jumping cotter. A pawl prevents the drum unwinding in the case of the horses backing. It also prevents accidents which might arise from a swingle-bar or pole breaking during the work. If such a breakage occurred, the strain on the cable would cause the drum to revolve backwards, carrying in its rotation the pole, which might injure animals, driver, or onlookers if too close.

The jerky, clicking noise produced by the falling of the pawl on the ratchet-wheel arouses the attention of the driver, renders the supervision easier, and breaks the monotony of the work. The radius of the drum is 12 inches, and reaches 16 inches when the cable is wound up. The pole is 16½ feet in length ; the moving power is, therefore, multiplied by 12·5. The speed of the plough may be increased a little, and the power diminished, by inserting wooden sectors between the flanges of the drum, which increases its diameter. The same result may be obtained by yoking the animals nearer the axis of rotation, that is to say, by diminishing the length of the pole, which is easily done by hooking the swingle-bar to hooks fixed on the pole for this purpose.

The animals, two or four in number, are yoked to one or two poles, as the case may be.

The cable is not fixed directly on the plough ; it is fixed on a cable-carrier, which is secured to the plough by chains. This cable-carrier, which is the characteristic of this system, consists of an axle and two large cast-iron wheels (Fig. 14).

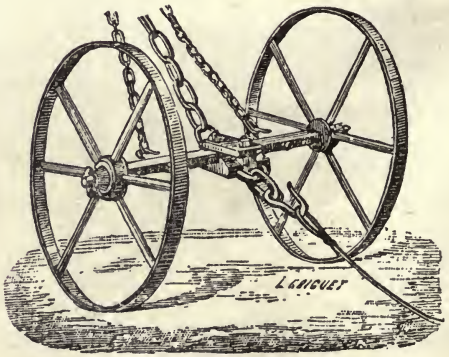

Fig. 14. – Cable-carrier used with Bourguignon's Gin.

It is provided with a hook, to hook on the end of the cable, and is connected to the plough by three chains, the two lateral serving to fix it askew to the direction of the plough.

The advantages of this device are as follows:—1st., it allows a very straight furrow to be turned, even if the cable pulls sideways, and therefore to only displace the gin every five or six furrows. The ploughman has only to work the side chains in the necessary manner, which is done without loss of time; 2nd, it prevents the plough from coming out of the ground, on account of the height of the point of traction. In fact, in most systems of gins it is necessary to alter the rear of the frame to keep the plough in position. This is usually done through the weight of the ploughman sitting on a seat fixed at the rear between the stilts.

The plough used by Bourguignon is the simple Brabant, specially constructed by Bajac for ploughing to a depth of 19½ to 24 inches, and provided with the following contrivance for carrying it back after each furrow has been ploughed:—The rear of the frame is traversed by an iron rod, threaded at one end, the other end carrying a small wheel; a handle nut allows the rod to be raised or lowered. When lowered the wheel rests on the ground, the body of the plough being lifted, and, resting on the small wheel and the wheels of the forecarriage, is easily transported. The height of the small wheel can be regulated, so that, when working, the plough rests on it; a rolling friction being substituted far the sliding friction of the frame. The Bajac plough is shown in Fig. 15, without the lifting device.

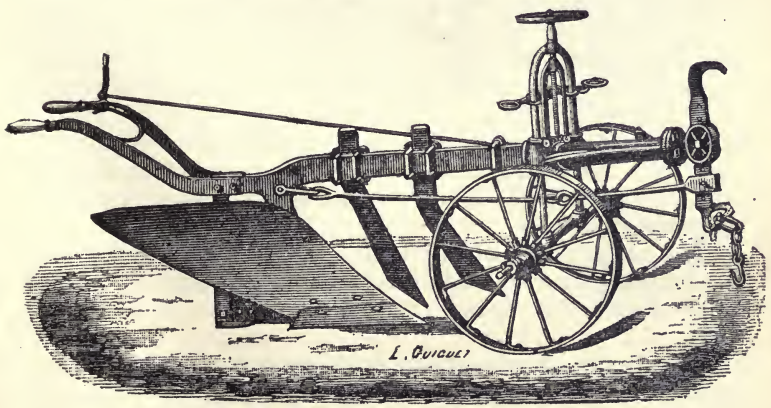

Fig. 15. Bajac's Trenching Plough.

Working.—This gin works like that of Grué. Installed on one side of the block, it pulls the plough from the opposite side. The rails on which it travels are kept in place by a few pegs. The non-ploughed headlands have the same dimensions as in the previous case.

Guyot's Horse-gin.

Guyot, implement maker at La Redorte (Aude), has devised a gin of great simplicity, which is easily worked. It obtained at the special show at Perpignan, in 1890, the first prize and a gold medal. It is a travelling gin, without either roller or rails.

Description.—It consists (Fig 16) of a large cast-iron bed-plate, provided with an axle to enable it to be shifted about ; during work the bed-plate rests on the ground. On the centre of the plate a vertical shaft revolves, kept in position at the top by a curb bolted on the plate. On this shaft the winding drum is keyed, which is 19½ inches in diameter, and on the top of the shaft two poles are fixed 11ft. 10in. in length. The ratio of the speeds are $\frac{1}{12}$, for, when the cable is wound, the average diameter becomes 2 feet.

The gin, resting on the ground, is fastened by means of an iron bar to a chain ancnored at each end. To displace the gin at each furrow the iron bar is simply slided along the chain, the traction on the cable then suffices to bring the gin opposite the furrow to be opened. The mode of displacement of this gin is identical to that of the fixed pulley of the Beauquesne system ; but, whereas the pulley drags out the anchors easily, on account of the large traction exerted on one of them (Fig. 7), the Guyot gin is easily kept in place, for the traction is exactly divided on both anchors, the iron bar being always placed in the prolongation of the bisectrix of the angle formed by the two parts of the anchoring chain.

The plough is made by Guyot. It is a simple Brabant, composed of a very strong beam, strengthened by a rolled joist girder, to which the different parts are fixed (Fig. 17).

The depth of ploughing is regulated by means of a screw placed at the rear of the beam. The width and the direction of the furrow are regulated by the position of the

cable hook, by means of a pair of pinions and a hand-wheel. The ploughman can, during work, adjust the regulator rapidly and easily.

The device for carrying the plough back to the starting point is ingenious. A small wheel, carried by a block and spindle, is, during the work, hooked between the handles. When the plough is out of the ground the spindle is inserted in a hole pierced sideways in the framework. By tilting the plough it is forced to rest on that wheel, the implement then running easily on the three wheels.

Working.—Guyot's gin is managed in the same way as the Beauquesne fixed pulley. The two anchors are fixed on one side of the block, the gin secured to the anchoring chain opposite the first furrow to be opened. As the work progresses the bar of the capstan is slided along the anchoring chain. The management of the plough is the same as in any other system. To facilitate the sliding of the gin-bar along the anchoring chain, this bar is tied to the gin by a small piece of chain winding round a small capstan. By acting on the latter, the gin is brought closer to the chain; the loosened bar is then easily shifted. During the carrying of the plough to the starting point a small brake is used to regulate the unwinding.

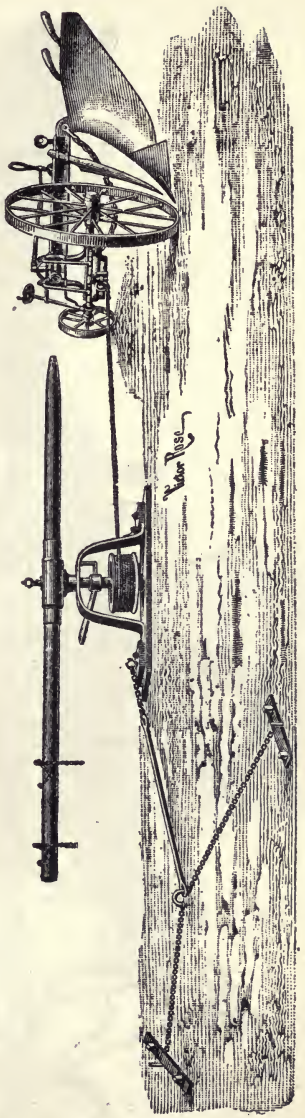

Fig. 16.—Guyot's Horse-gin.

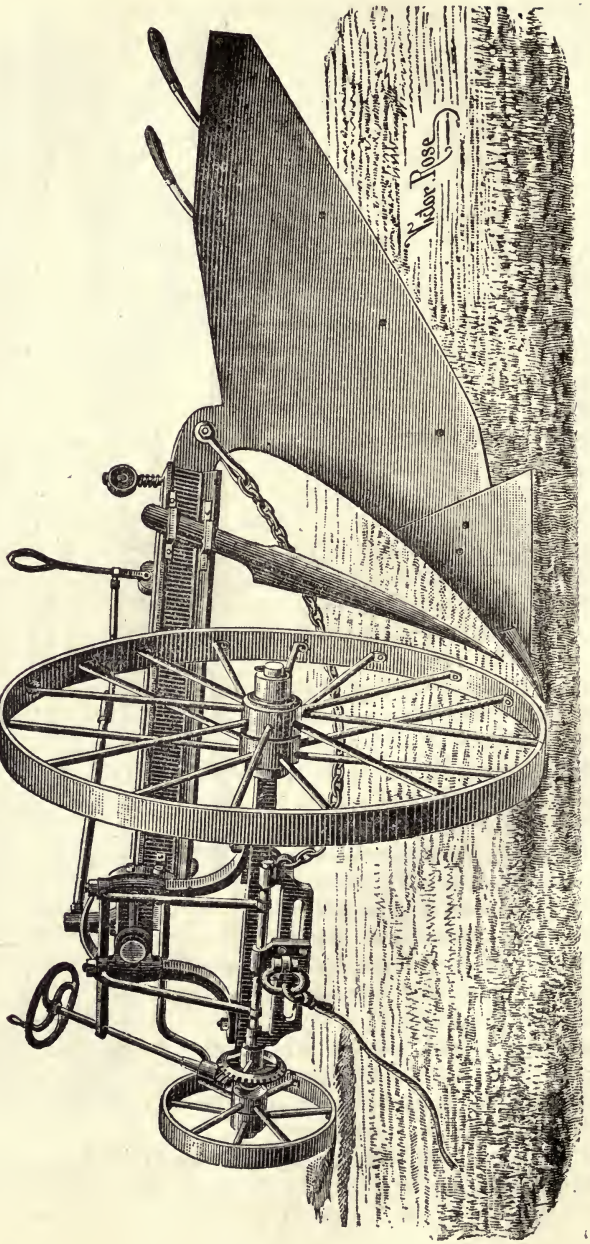

Fig 17.—Guyot's Trenching Plough.

The Guyot gin is one of the simplest and most practical; its cost is only £34, the carrying wheels cost £4, the plough £28, the cable, of 274 yards, £10.

Vernette's Horse-gin.

The gin designed and made by Etienne Vernette, of Beziers, is worked like those of Grué or Bourguignon, by displacement on rails along the headland.

Description.—It is composed of a winding drum 23½ inches in diameter (Fig. 18). This drum revolves round a strong

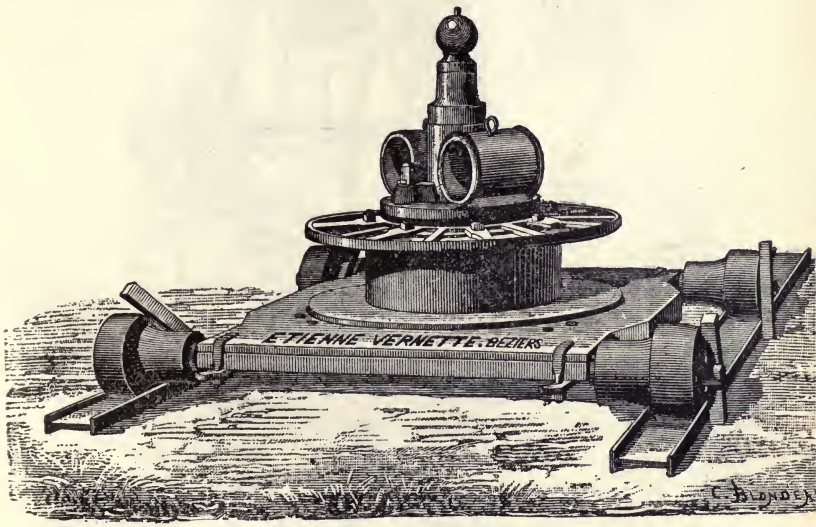

Fig. 18.—Vernette's Horse-gin.

steel shaft keyed on a cast-iron cross, bolted under a cast-iron bed-plate. There is no framework, therefore the cable can take any direction. The bottom flange of the drum is countersunk in the bed-plate, which prevents the cable, when winding up, from being caught under the drum. The whole machine is carried by four massive rollers. The socket-head for the two poles runs loose on the same shaft as the drum; the drum and the socket-head are clamped together by means of two cotters. When the cotters are in place, the animals wind up the drum in their circular motion; when taken out, the drum is disconnected, and the weight of the socket acts as a brake during the unwinding.

If the roads are in good order the animals may be yoked directly on the gin, which travels on the rollers; if not, it may be carried on a dray, or on a truck made specially for

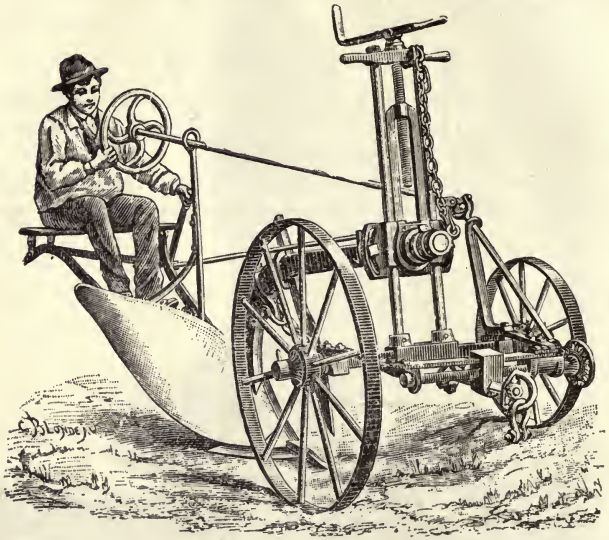

Fig. 19.—Vernette's Trenching Plough.

the purpose. During work the machine is displaced on a pair of rails made of rolled joist girders. Pegs prevent any displacement in the direction of the cable.

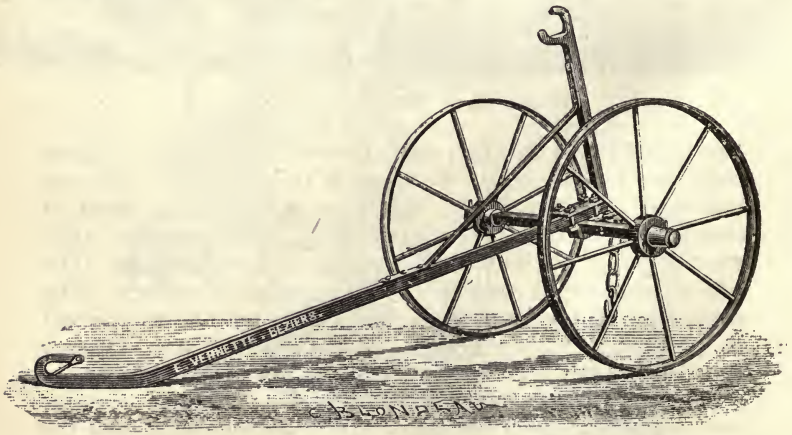

Fig. 20.—Patent Automatic Carrier for Vernette's Plough.

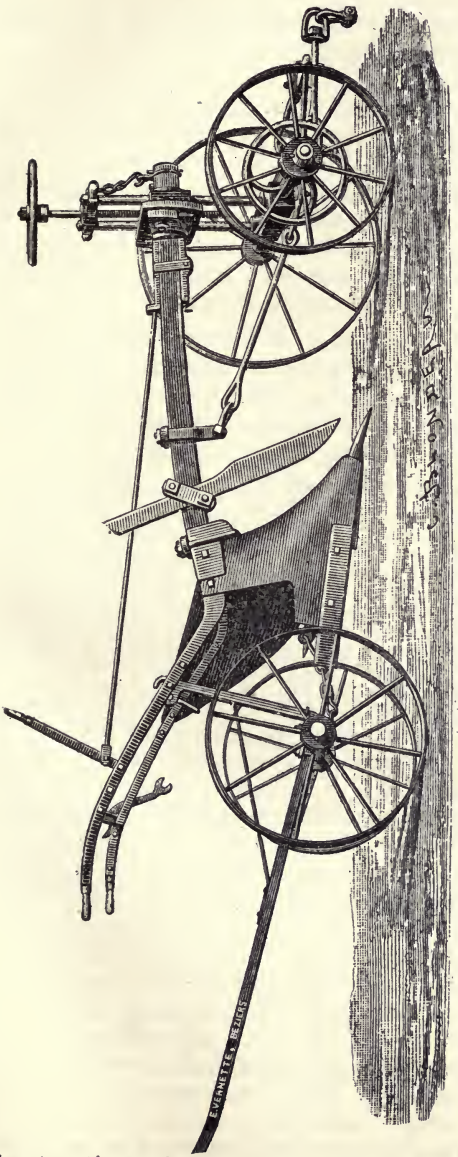

Fig. 21. Plough placed on the Automatic Carrier.

Working. — It works like any other movable gin. It is strongly built, well studied in details, and only costs £34. It is one of the most practical machines offered to viticulturists. It generally hauls a plough specially made for it by the same firm (Fig. 19). It is a simple Brabant, provided with a seat for the ploughman, who can easily regulate and direct the plough by means of a lever placed in front of him. The depth of ploughing is adjusted by a screw on the forecarriage, the width by the lateral displacement of the wheels. A special truck (Fig. 20) is easily placed under the frame for returning the plough to the starting point. The wheels of the truck are fixed on a right-angle lever in such a way that the traction of the horses lowers the wheels, lifting the plough (Fig. 21).

This plough costs £30 with the seat; £28 without the seat. In this case the hand-wheel for regulating is worked from the side as shown in Fig. 21.

Pelous' Horse-gin.

Pelous, an implement maker at Toulouse, endeavoured to remedy two of the inconveniences generally met with in horse-gins:—1st, the defect of want of stability and the tendency to tilting under the strain of the cable; 2nd, the defective winding of the cable on the drum.

Description.—It is composed of a winding drum 19½ inches in diameter, revolving round a vertical shaft, carrying a socket head, with two poles 11ft. 10in. in length. The motive power is multiplied by twelve. The machine can be mounted on wheels for shifting about. During work it is displaced on four rollers rolling on two rails. The machine is light. It only weighs 11cwt. 3qrs. To prevent tilting, Pelous places on the bed-plate two wooden cases of about 17½ cub. feet each in capacity, which are filled with earth; the additional weight is then 25cwt. 2qrs. to 29cwt. 2qrs. This is quite sufficient to insure the stability of the machine. When the work is finished the cases are emptied, and the weight to shift about is only 11cwt. 3qrs.

The cable, instead of winding freely round the drum, is guided by a small pulley fixed on an iron arm working with a slow up and down movement. This movement is given by means of a cam-wheel worked by means of a pinion. The cam makes one revolution for 23 revolutions of the drum; the guiding pulley rising during the first half revolution of the cam, and lowering during the second half. It is easy to conceive that the cable, guided in this way, will wind on the drum in a regular helix, all the turns being in perfect contact. This ingenious device, used for a very long time in the Fowler steam system, acts very well, on the condition that the cable be of an even diameter. If, on account of the wear and stress, the cable does not retain its original diameter, or, if a cable of a different diameter is used, the winding ceases to be regular. This cable guide, indispensable with the Fowler machines, which have large winding drums, and which impart a great speed to the cable, does not seem useful for horse-gins, which always have small drums, and work at a slow rate. It complicates the machine, and

increases its cost by £12. Up to the present no horse-gin has had this additional device, and, if the winding of the cable is not always very regular, this defect, however, is not of much importance. It is, as a matter of fact, easy to insure good winding. All that is necessary is to moderate the unwinding during the carrying back of the plough to the starting point, so as to prevent the last turns from becoming slack and overlapping one another. If this precaution is followed, defective winding never occurs.

The Pelous gin, with 274 yards of cable 0·6 inch in diameter, costs £32. With a cable guide, it costs £44. It hauls a strong trenching-plough, with a seat for the ploughman, which costs £28.

Working.—This machine works like those already described.

Mechanical Yield of Horse-Gins.

It is interesting to know the mechanical yield of gins—that is to say, to estimate the loss of power due to friction and other *detrimental resistance* of the machine, to find out the ratio between the moving power (horses) and the resistance (plough). Experiments were made by Chabaneix, of the School of Agriculture, Montpellier, in August, 1887, at Candillargues, with Beauquesne's gin.

The large traction *dynamometer* (power-gauge), of the School of Agriculture, was fixed to the bridle of the plough to measure the resistance offered by it. Another smaller dynamometer, belonging to the school, was interposed between the swingle-bar and the pole to measure the effort developed by the animals. The ratio between these two expresses the mechanical yield of the machine and the difference, the detrimental resistance. Two consecutive trials were made, and gave the following results:—

Detrimental resistance:

1st trial	... 11·8	per cent. of the total motive-power.
2nd ,,	... 10·3	,, ,, ,,
Mean	... 11	,,

Yield of the machine:

1st trial	... 88·2	per cent.
2nd ,,	... 89·7	,,
Mean	... 89·0	,,

These figures show that the yield of the machine is considerable, and the losses due to the mechanism almost

negligible ; in any case, they are much less than those resulting from the union of the animals in a single team executing the same work by direct traction on the plough.

Area Ploughed.

The surface ploughed per day with a horse-gin depends greatly on the length of the furrows and the size of the plot. It depends also on the experience of the workmen, and the skill with which they execute the different works. It may be approximately calculated as follows :—The horse at the pole travels at an average speed of 35½ inches per second, that is to say, 177 feet per minute. The length of the pole is generally to the diameter of the drum as 10 is to 1 ; the plough travels with a speed ten times less, that is to say, 17·7 feet per minute. If the width of the sod is 19½ inches, the surface ploughed will be 28·5 square feet per minute ; and for ploughing 4 poles it would require 37 minutes, without stoppage, interruption, or breakage. But, taking the plough back to the starting point, accidental stoppages, and unforeseen accidents, absorb a time equal to that usefully used for ploughing, so that one hour and fifteen minutes are usually required to plough 4 poles. In one day's work of ten hours an area of 32 poles can, therefore, be ploughed. With the movable gins, the conditions are more favorable, 4 poles per hour can be ploughed, that is to say, 40 poles per day. One cannot depend on more rapid work.

In shows and in public trials greater speeds have been attained ; but the work required from the men and animals was excessive, and could not be performed continuously.

Cost of Trenching or Subsoiling with Horse-gins.

The estimation of the cost comprises—1st, the interest on the outlay for plant ; 2nd, the expense for wear and tear ; 3rd, the daily expense of the work.

A trenching plant, gin, plough, and accessories, cost on the average, £80. This sum must be written off in ten years. Taking the interest on the capital at 5 per cent., the amount to be written off per annum is £10 10s. If we assume that we plough 12⅔ acres every year, and that we plough 40 poles every day, the machine will work 50 days in the year. The daily expense to be written off is $\frac{£10\ 10s.}{50}$ = 4s. 2d.

The wear and tear runs annually into 5 per cent. of the capital. That is to say, a daily expense of 1s. 7d. A driver for the horses, two ploughmen—one for the plough, the other for the pulley—a boy to drive the horse pulling the plough back to the starting point—such is the indispensable staff.

The daily expense incurred by this is:—

3 workmen, at 2s. 4½d.	...	7s.	1½d.
1 boy, at 1s. 2¼d. ...	...	1s.	2¼d.
3 horses, at 3s. 2d.	...	3s.	2d.
Total ...	...	11s.	5¾d.

This 11s. 5¾d., added to 4s. 2d. to be written off, to 1s. 7d. for wear and tear, bring the daily expense to 17s. 2¾d. As the area ploughed is 40 poles, the ploughing of 1 acre costs, roughly, £3 8s. 11d.

If the machine is worked less than 50 days in the year the cost per acre will be a little higher, for the sum to be written off yearly will be divided over a smaller number of days; if, on the contrary, the machine is worked a greater number of days, the price will be reduced.

STEAM WINDING DRUMS.

The same two classes may be established for steam drums. Some are stationary, that is to say, installed at the beginning of the work in a suitable place in the block till all the ploughing capable of being done with a certain length of cable is completed. Some are displacing, that is to say, gradually travel along a headland as the work proceeds.

In the first class we find the Beauquesne, Vernette, and Grué machines; in the second, those of Guyot, Pelous, and Pécard.

Beauquesne's Steam Winding Drum.

This was first placed on the market in 1887. It closely resembles his horse-gin.

Description.—A winding drum T (Fig. 22) revolves round a vertical shaft, carrying cogs on both its flanges, the upper one being smaller in diameter. Each of these cog-wheels gears with a pinion; the two pinions run loose on their shaft, but they may be alternately thrown into gear with a lever L. On the top of this shaft a bevel cog-wheel is keyed, gearing with a bevel pinion, fixed on a horizontal shaft

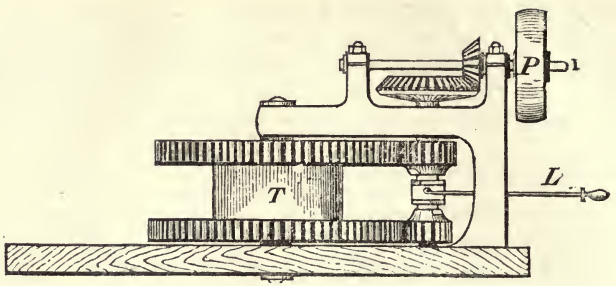

Fig. 22 —Beauquesne's Steam Winding Drum.

carrying a belt-pulley P. For shifting from one place to another, the machine may be mounted on wheels. When working, the wheels are removed, and the machine buried level with the bottom flange of the drum. The portable engine is fixed at a suitable distance, its pulley connected to the pulley of the drum by a belt.

Working.—The winding drum and the portable engine are usually installed in the middle of the headland. At one extremity of this headland a fixed pulley is anchored, the same as is used for the horse-gin. The drum of the capstan being disengaged, the cable is unwound, passed over the fixed pulley, and fastened to the plough, which is taken to the starting point. The portable engine is then started, the pinions thrown into gear, and the plough hauled. When it reaches the fixed pulley, the plough is thrown out of gear to lift it out of the ground, and is stopped by throwing the drum out of gear. The plough, placed on a trolley, is taken back to the starting point by a horse or pair of bullocks ; meanwhile the fixed pulley is displaced to an extent equal to the width of the furrow.

If the top pinion is thrown into gear, the drum revolves with greater speed, the plough travels quicker, but the traction decreases. If, on the contrary, the bottom pinion is thrown into gear, the speed diminishes while the traction increases. If the engine is powerful enough, the top pinion should be used. If not, the lower one.

We must notice that the engine does not work while the plough is taken back. This time is used by the engine-driver to raise the steam pressure, which, if the engine is not strong enough, might have diminished. One can therefore use a relatively small power engine, which would be insufficient if continuous work was required from it.

The capstan is constructed to work with an engine of 12 H.P., but it is generally worked with a 4 to 8 H.P. engine.

The cable may work in any direction. Therefore, one may, without displacing the machine, plough a block of 20 to 22½ acres with a cable 328 yards long. The headlands may be ploughed without shifting the plant. It suffices for this to anchor the fixed pulley in a suitable position. The non-ploughed headland on the engine side is 23 to 26 feet in width ; on the opposite side, 10 feet.

The plough is the same as used with the horse-gin ; it can work to a depth of 20 to 24 inches, turning a sod 20 inches wide.

The working of the plant requires three men—one engine-driver, one ploughman, one attendant—to manage the fixed pulley. A horse and a boy are also required to return the plough to the starting point. The capstan, with accessories, and 328 yards of cable, costs £160, plough excluded. The whole plant, plough, engine (6 to 7 H.P.), capstan, and accessories, costs £400.

Vernette's Steam Winding Drum.

Vernette builds two different types.

Description.—The first is simply his horse-gin, in which the pole socket-head is replaced by a toothed-wheel gearing with an endless screw, the shaft of which carries a pulley (Fig. 23). The supplementary mechanism is carried by a framework bolted on the bed-plate, and carrying the shaft through collars at the top. The cog-wheel and the drum are clamped by two cotters.

The second type resembles this, the only difference being that instead of an endless screw a pair of pinions are used to transmit the power. On the drum a bevel cog-wheel is keyed, gearing with a bevel pinion. On the shaft of the drum a cog-wheel is fixed, gearing with a pinion, on the shaft of which the pulley is fixed (Fig. 24).

This second type is preferable, the transmission by cogs giving a higher yield than that by endless screw.

They are both worked by connecting the pulley to the fly-wheel of the engine.

Working.—The capstan is placed on the ground, on its rollers, and fixed by a few pegs in such a position as to run

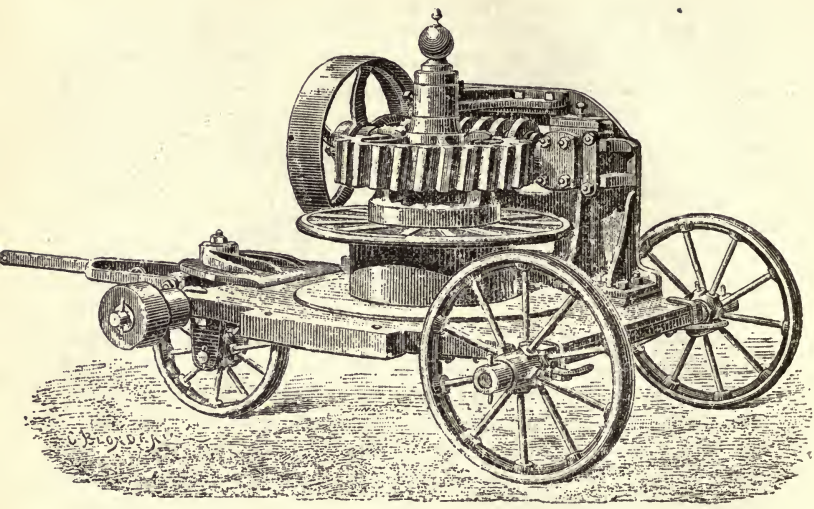

Fig. 23.—Vernette's Steam Winding Drum.

the furrow on the greater length of the block. The engine is placed in a suitable position, and connected by a belt generally 26 to 32 feet in length. The pulley is fixed on the opposite headland in the same way as for the Beauquesne machine.

The anchoring is done by means of iron pegs, disposed like an open fan at both ends of the anchoring chain, and

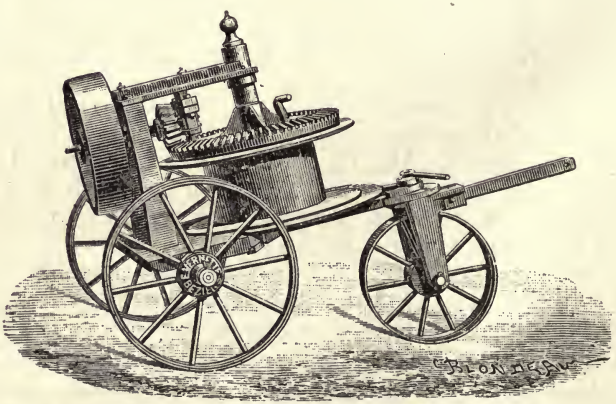

Fig. 24.—Second type of Vernette's Steam Winding Drum

joined to it by an iron bar. With an 8 H.P. engine working at 150 revolutions per minute the drum performs eight revolutions, and the cable travels at the rate of 69 feet per minute.

This machine is simple, strong, well constructed, and works satisfactorily; the only drawback is the difficulty of anchoring the fixed pulley.

Its cost is £92 without cable or plough. The cable, 0·55 inch in diameter, costs 4d. per foot; the plough, which is the same as for the horse-gin, costs £30. The whole plant, therefore, exclusive of the engine, costs £140. With an 8 H.P. engine costing £220 to £240, the whole plant costs £360 to £380.

Grué's Steam Winding Drum.

This machine can be used either with steam or horses. It is simply the machine shown in Fig. 10 (page 28), slightly modified.

Description.—The winding drum, T (Fig. 25) revolves round a vertical shaft, moved by a large cog-wheel A

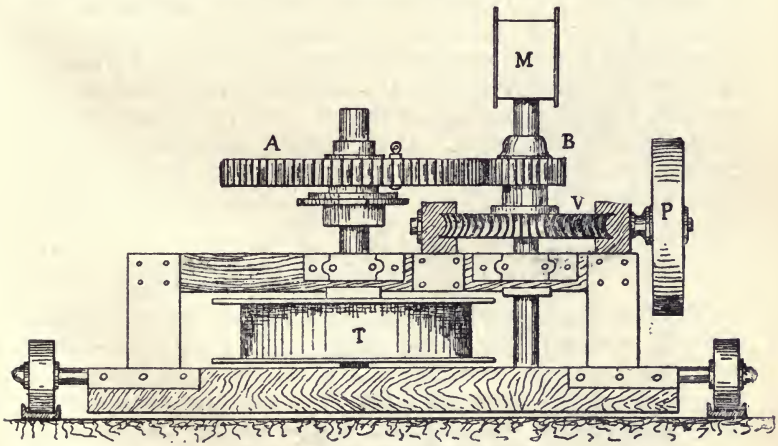

Fig. 25.—Grué's Steam Winding Drum.

gearing with a pinion B, on the shaft of which a pole socket-head M is keyed above; a cog-wheel V is keyed below, gearing with an endless horizontal screw, on the shaft of which the pulley P is fixed, which receives the belt of the engine. The large cog-wheel A is clamped to the drum by a cotter. The drum is allowed to run loose by lifting the cotter.

To work at a greater speed the endless screw and its cog-wheel may be fixed direct on the drum-shaft. In this case the machine resembles that of Vernette (Fig. 23). For medium depths, if the soil is light and if one has a powerful engine, the endless screw should be connected direct on the drum-shaft. If the motive power is small, and if the soil is stiff, and a greater depth of cultivation necessary, the endless screw should be connected to the pole-socket shaft as shown in the figure. If it is desired to work with horses, the endless screw is removed, and the machine worked like an ordinary horse-gin. The winding drum travels along the headland on its rollers. The engine connected by the belt follows it. It can also be used in a fixed position.

Working.—When this winding drum is worked with an engine, it is preferable to install it in a stationary position, the cable passing over a fixed pulley. The frequent displacements of the engine necessitated entail considerable loss of time. With animals, on the contrary, the displacement can be quickly done.

The only interesting peculiarity of this machine is the adjustability of the speeds it is worked at, according to the motive power, the state of the land, and the depth to be ploughed. This adjustment of speed, the utility of which is not apparent when horses are used, is, on the contrary, an excellent item when steam-power is used, on account of the varied power of engines. It is evidently important to work rapidly when one has a 8 to 12 H.P. engine, and also to be able to work the machine with an engine of 3 to 4 H.P. only if necessary.

Guyot's Steam Winding Drum.

The Guyot steam winding drum is a displacement capstan, worked in a very ingenious manner. The portable engine and the drum are carried on two strong iron beams, the whole plant travelling on rails. The stability, therefore, is very great, as the whole weight of the engine and drum is opposed to the traction of the cable. The lateral displacement is also rendered very easy.

Description.—The wheels of the portable engine rest on two rolled joist girders, braced together at the required distance apart. The capstan is fixed in front ; it consists of a mechanical drum (Fig. 26), on the shaft of which a cog-wheel is keyed, gearing with a pinion, on the shaft of which

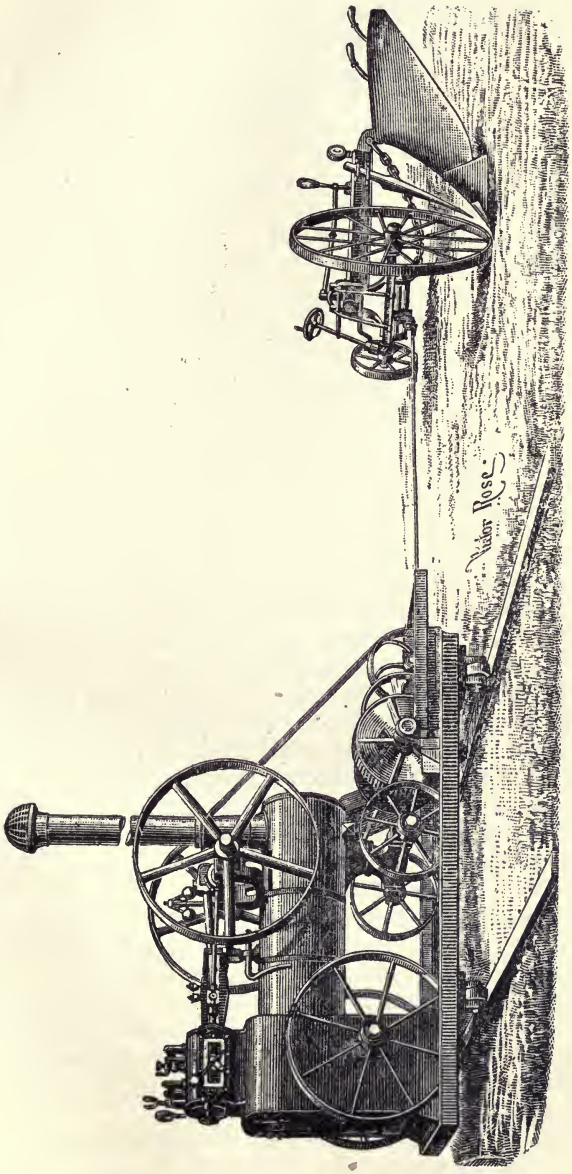

Fig 26.—Guyot's Steam Winding Drum.

a cog-wheel is fixed, gearing with a second pinion, keyed on the shaft which carries the pulley; this is connected by a belt to the pulley of the engine. The two machines, therefore, form one. The iron frame rests on rollers, rolling on rolled joist girders. The tires of these rollers are perforated with holes in which levers are engaged for displacing the system. The axles of the rollers may move obliquely to allow the system to be displaced easily on a curved or sinuous headland. When the end of the block is reached, it is easy by turning it at 90° to plough the headland. In this case special curved rails are used. A brake to control the unwinding, and a gearing lever complete the machine. The model exhibited at the Perpignan Show had, in addition, an arrangement allowing the plough to be hauled back to the starting point. For this purpose the intermediate shaft had a small drum keyed on to it, on which a thinner cable was wound. This, after passing over the fixed pulley, was tied to the rear of the plough. A lever threw it in or out of gear.

Working.—The working of this system is very simple; the frame carrying the engine and capstan is installed on the shortest headland. The thinner cable fastened to the rear of the plough hauls it to the opposite headland. When the plough reaches it, the small drum is thrown out of gear; this throws the large drum into gear, and the plough is hauled. When the plough reaches the system the small drum is thrown into gear, hauling it back to the starting point, and so forth.

In the meantime the system has been displaced laterally.

The fixed pulley and the small cable runner are indispensable to guide the cable. Their anchoring, however, is simple, for they have only a small effort to sustain. The pulley and runner may be displaced during work without waste of time. The non-ploughed headland on the engine side is 39 feet in width; on the opposite side, 10 feet.

The plough is the same as that used with the Guyot horse-gin. With an 8 H.P. engine working at 140 revolutions the plough travels at a rate of 59 feet per minute.

Three men are required for the working; one engine-driver, one to work the capstan, and another to work the plough. If the small drum is used, another man is required to shift the runner and the fixed pulley, in the other case a horse and a boy.

This machine works perfectly; its management is simple, and the loss of time is reduced to a minimum. Only the

setting up and dismantling are somewhat difficult, on account of the weight of the pieces to be moved. To haul the machine on the frame, the capstan is fixed to one end of it, the cable fastened to the forecarriage of the engine, and worked by hand; it takes twenty minutes to mount in position; the setting up of the whole machine takes two hours. For shifting; the frame, capstan, and accessories are removed on an ordinary dray. The weight of frame and capstan is 2 tons 8 cwt. Its cost, without either cable or plough, is £112. With cable and plough, the plant costs £134; with small extra winding drum, £176. The cost of the whole plant, with an 8 H.P. engine, costing £240, is £392. With a fixed pulley and the runner it reaches £416.

Pelous' Steam Winding Drum.

Resembles that just described, but has three interesting additions. First, it can work both ways; second, the winding of the cables is guided by a special device; third, the lateral displacement of the system is done automatically,

Description.—As in the Guyot system, the engine and capstan rest on a large strong frame made of rolled joist girders. The capstan is double. That is to say, made of two drums, each worked by a pair of cog-wheels. To each drum an endless screw is geared, working a lever guiding the winding of the cable. The throwing in or out of gear of the drum is done by friction, which renders the throwing out of gear easy whatever the traction effort be. It also serves as a break during the unwinding. The large frame rests on four rollers, rolling on iron rails; two of them are geared with an endless screw allowing their automatic displacement. On the opposite headland a pulley is fixed to an automatic anchor made of a truck travelling laterally, the stability of which is secured by a case 141 cubic feet in capacity, which is filled with earth. The lateral displacement of this truck on the headland takes place on rails, and is obtained by means of an endless screw and a cog-wheel; one turn of the screw corresponds to a displacement of 2 inches.

The Bajac balance-plough, shown in Fig. 27, is used; it is made entirely of steel, and possesses great strength.

The depth is obtained by means of two screws placed on each side of the forecarriage. The frames of the two ploughs are united together by a strong steel bar, which renders the system very rigid. The beam can be displaced

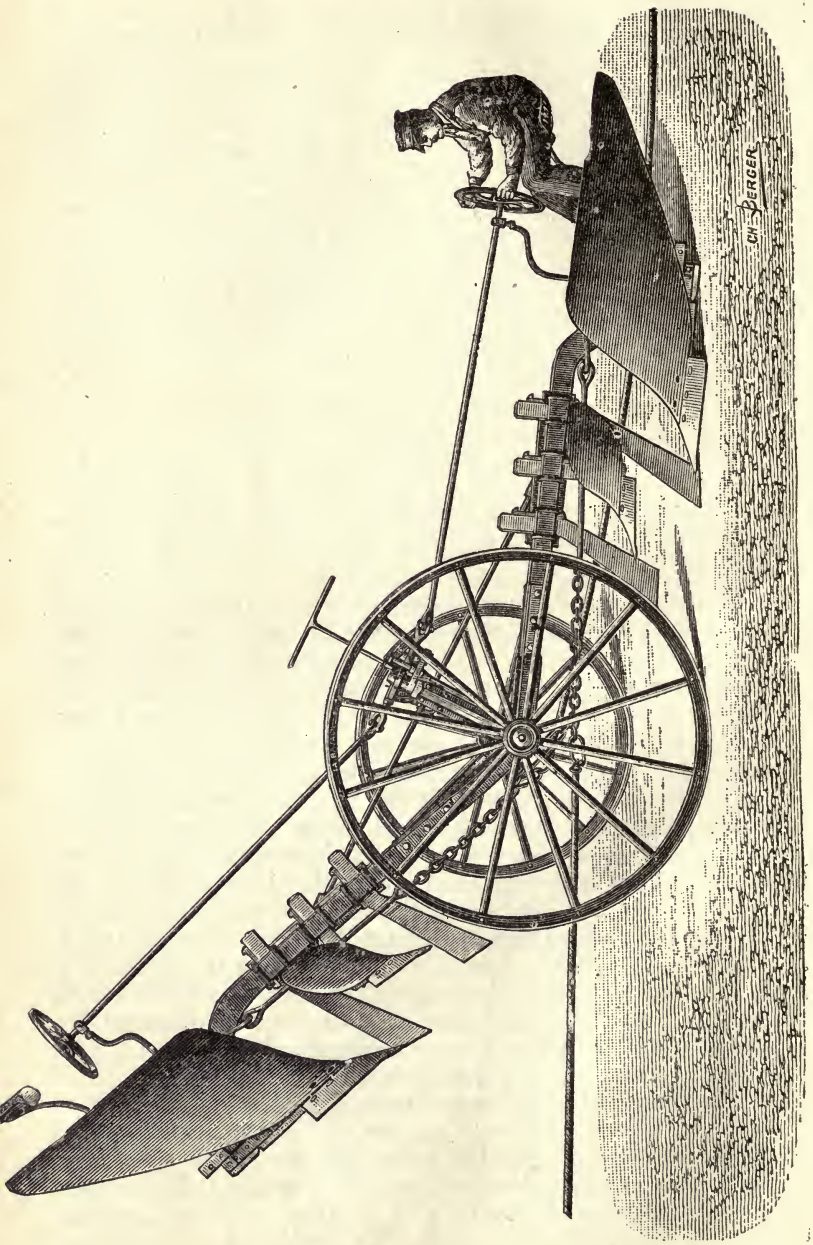

Fig. 27.—Bajac's Balance-plough.

laterally on the forecarriage, according to the width of the sod to be turned; during the work the ploughman guides the plough by altering the angle of the wheel axle on the beam. The traction of the cable is regulated by a hook which can be displaced on the forecarriage. This plough is connected to the capstan by two cables; one is 328 yards in length, and 0·7 inch in diameter, and hauls the plough directly; the other, which is 656 yards long and 0·74 inch in diameter passes over the automatic anchor and is wound round the second drum.

Working.—This machine is easily managed; the system is installed on one side of the block, the pulley on the other. Each of the drums are thrown into gear alternately, the winding of the cables causing the plough to travel backwards and forwards, the system being displaced the necessary distance before each furrow. Four men are required; one rides the plough, one works the pulley, two attend to the steam winding drum.

With a 12 H.P. engine working at 180 revolutions the plough travels at the rate of 88 feet per minute.

The non-ploughed headland on the engine side is 43 to 46 feet wide; on the opposite side, 20 feet. To plough the headland, the automatic anchor has to be carried from one end of the block to the other; this is a tedious operation.

This winding drum weighs 3 tons 10 cwt., and costs £240, cable included. The plough costs £80. With an engine of 10 H.P., costing £300, the whole plant involves an outlay of £620.

Pelous' plant is well studied in all its details, and strongly constructed. We may wonder, however, if its high cost and expensive working are justified in face of the rate of work, and if the two improvements are really practically useful. The calculation of the cost of working per acre in the case of winding drums working one way, as will be explained later on, shows on which side the advantage lies. We see the area ploughed every year must be at least 80 acres for the double-effect drum to be more economic than the single-effect drum. Therefore it is only suited for contractors.

The usefulness of the winding guides is questionable; without them the winding is fairly regular, and accidents are rare enough to justify discarding this unnecessary complication.

It should be noticed that this device only works well while the cable is new, and retains the diameter for which the winding guide was made. If the wear or the natural lengthening of the cable diminishes its diameter, the winding is more defective than if there were no guide.

Finally, the automatic displacement of the system, which is very ingenious indeed, does not seem to be very useful. Its mechanism is complicated, and its management requires a prudent and skilful man to prevent the system becoming derailed. And what is more, the two rollers being fixed on the same shaft, renders it impossible for the machine to travel obliquely.*

The machine could therefore be simplified with advantage. Transformed into a simple effect drum, the complicated mechanism being removed, but the details of construction being preserved, this machine would be more favoured by growers than the double effect machine exhibited at the Perpignan Show in 1890.

Pécard Bros.' Steam Winding Drum.

Messrs. Pécard Bros., of Nevers, construct a machine having a certain analogy to that of Guyot. Engine and drum are carried on a strong frame. There is a large drum for the traction cable, and a small one for taking the plough back to the starting point, the only differences being that different speeds can be obtained and that the lateral displacement of the system is automatic, as in the case of Pelous' winding drum.

Description.—The portable engine, 7 to 8 H.P. generally, is carried by a strong frame on which the capstan is bolted (Fig. 28). The system is carried by six rollers running on rails. The fly-wheel of the engine is connected by a cross-belt to the pulley of the drum, which has a double cog-wheel gearing. Two levers enable the combination of the cog-wheels to be modified and four different speeds obtained. One of these levers also serves to disconnect the large drum. A small drum running at two speeds is keyed on the intermediate shaft.

The automatic displacement of the system is effected by another cross-belt passing over the small fly-wheel of the engine. A double cog-wheel gearing with an endless screw

* This is comparatively unimportant in Victoria, as the blocks are generally rectangular. (Trans.)

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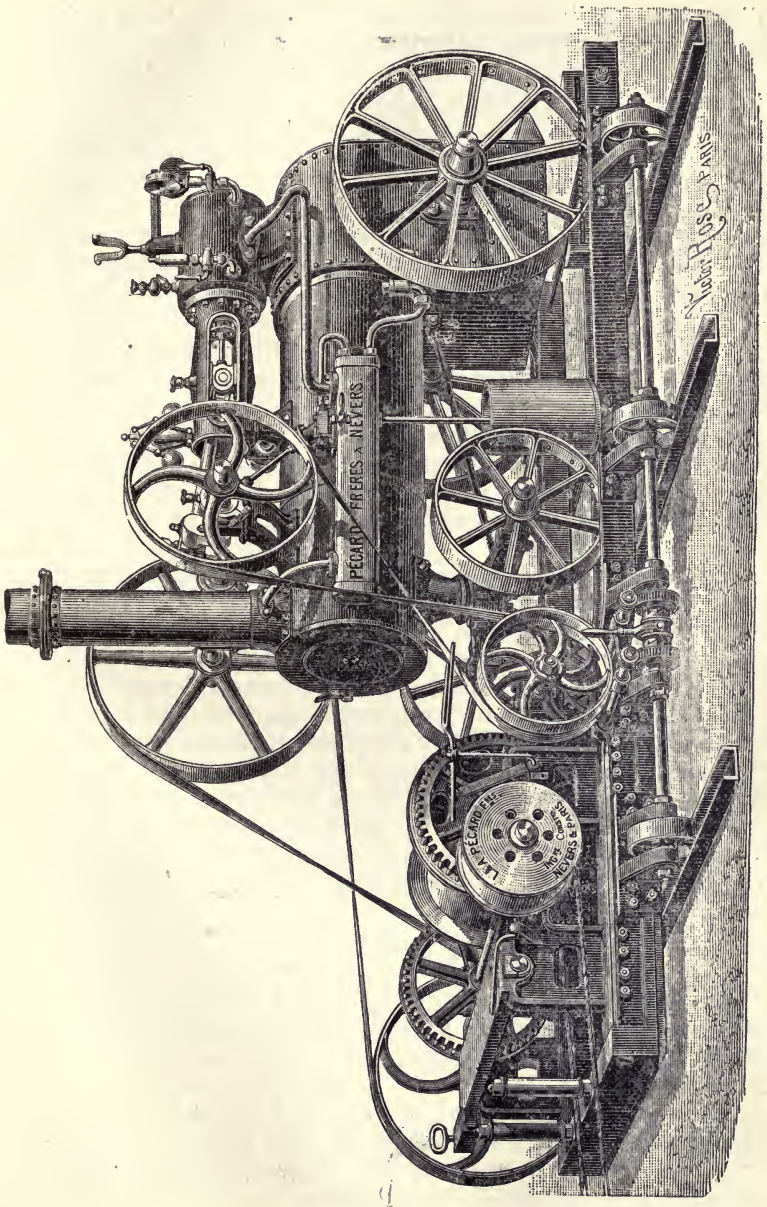

Fig. 23.—Pécard's Steam Winding Drum.

allows it to be displaced backwards or forwards. After each displacement the belt is shifted on to a loose pulley. The system is installed on one of the headlands, and the plough fastened to the large cable. The small cable, known as the returning cable, is made fast to the rear of the plough, after passing over the fixed pulley anchored on the opposite headland. When everything is in place, the small drum being thrown into gear, the plough is pulled backwards to the starting point. The large drum is then thrown into gear, and one of the four speeds applied according to the soil and the depth of ploughing. When the plough reaches the end of the furrow the large drum is thrown out of gear, and the small one thrown into gear, the plough hauled back, and so forth. In the meantime, the system has been displaced automatically.

With a 6 H.P. engine, working at 150 revolutions per minute, a plough is hauled at a rate of 58ft. 4in., 68ft. 10in., 82ft. or 96ft. 8in. per minute. The plough is hauled back at a rate of 164 feet to 197 feet per minute, as the case may be.

Four men at least are required for the management of this outfit—two for the capstan and engine, one to ride the plough, and one to attend to the automatic anchor and the cable runner.

Pécard Bros.' device is undoubtedly one of the most ingenious. But it is more complicated than that of Guyot, and would be advantageously simplified by doing away with the automatic displacement of the large frame engine. This mechanism is not only useless but also cumbersome, for it is impossible to work in any other but a straight line, and cannot be turned round at the completion of the work in order to plough the headlands. Its cost, exclusive of engine and plough, is £100.

Pineau's Steam Winding Drum.

At the Agricultural Show held at Avignon in 1891, a steam winding drum was exhibited, constructed by Pineau, of Moulins (Allier), designed after the well-known style of Howard.

Description.—The portable engine is fixed in a set position in the middle of the headland. The capstan, made of two drums, revolved by two pairs of cog-wheels, is carried by a truck, the shafts of which are tied to the rear of the

engine. A platform is fixed on the shafts for the engine-driver and the fuel. The capstan is connected to the engine by means of a belt.

The extremities of a cable, which travels all round the block to be ploughed, are fixed one to each drum.

Fixed pulleys, anchored in suitable positions, carry the cable. A gearing device enables the engine-driver to alternately throw either drum into gear. The plough, being fastened in the middle of the cable, is therefore hauled backwards and forwards. It is a balance plough. At each furrow the two end pulleys are displaced for a distance equal to the width of the furrow.

To facilitate this displacement, these pulleys are carried on automatic anchor-trucks, similar to those of the Fowler system. These anchor-trucks are mounted on discs of iron with sharp tires, penetrating the soil on account of the load. The anchor resists well any traction perpendicular to the plane of the discs, while movement in the direction of the discs offers only slight difficulty. To obtain the necessary translatory movement of the anchor, a small cable is fastened at one end to a fixed point, an old stump or post for instance, the other winding round a small capstan carried by the anchor-truck. While the plough is travelling away from the anchor, the small cable is slackened a little, and as soon as the engine begins to pull the plough forward, the anchor-truck rolls on its discs, and moves a distance equal to the length slackened by the small cable. The moving of the anchor truck is therefore done automatically without any waste of time.

Working.—The plough opens furrows parallel to the headland where the engine is fixed, the work beginning on the opposite headland. At the start, the cable completely hems round the block; as the work progresses the rectangle formed by the cable gradually diminishes. The plough travels at a rate depending on the power of the engine, the nature of the soil, the depth of the ploughing, &c. This rate may reach 118 feet per minute, but is generally from 82 feet to 98 feet.

One engine-driver is sufficient to attend to the engine and capstan. Three men are required to attend to the plough and anchor-trucks.

The whole plant costs £532.

The working of the machine is satisfactory. The anchoring of the two fixed pulleys, which are not carried by anchor-trucks, is the only difficulty. Anchoring-plates, as already described, give the best results.

Mechanical Yield of Steam Winding Drums.

There is no definite record published on the mechanical yield of steam capstans. However, we may estimate it approximately by comparison with ordinary horse-gins. The only mechanism interposed between the motive power and the resistance is one or two pairs of cog-wheels, as in the case of horse-gins.

Numerous dynamometric trials made on horse-gins have shown that the yield varies between 70 and 80 per cent., and that in the case of a gin provided with two pairs of cog-wheels the yield is 75 per cent. This figure can be regarded as the yield of steam winding drums.

Area Ploughed.

As in the case of horse-gins, the area ploughed daily varies greatly, and depends on the length of the furrow, the size of the block, the motive power, the experience and skill of the workmen, also according to whether it is a simple or double effect capstan. If we assume an average rate of travelling of the cable of 65ft. 7in. per minute, and a sod 19·7 inches wide, the area ploughed in one minute is 107·6 square feet. Seven hours are required to plough 1 acre, assuming that there is no interruption. But the hauling back of the plough (simple-effect capstan), unforeseen accidents, ploughing of the headlands, reduce this area to half. Therefore 14 hours are required to plough 1 acre, that is to say, about one day and a half, assuming that we work ten hours a day.

With a displacement capstan, Guyot or Pécard, for instance, and with a powerful engine it is possible to work one acre per day. But it is safer to reckon on one and a quarter days.

With a double-effect capstan, Pelous or Pineau, for instance, the work is more rapid. The cable travels at the rate of 88ft. 6in. per minute, ploughs 145 square feet per minute, or 966 square yards per hour. Assuming that one-third of the time is wasted, this means an area of 240 poles per day of ten hours. One acre may therefore be worked in 6 hours 40 minutes.

If we take into account the installation of the plant, it is far safer to reckon on one day per acre.

Cost of Trenching or Subsoiling with Steam Winding Drums.

Three forms of expenditure must be taken into consideration.

1st. The writing off of the cost of the plant.
2nd. The wear and tear.
3rd. The daily cost of the work.

A.—Simple-effect Plant.

Average cost £400. This capital is to be written off in eight years. If we assume that we plough 80 poles per day, and work 60 days in the year, we arrive at the following:—

	Per Annum. £
Writing off and interest at 5 per cent. of £400 in eight years	71
Wear and tear of material at 3 per cent. of the capital	12
Total ...	£83

Equal to £1 7s. 4d. per day.

The daily expenditure is reckoned as follows :—

	£	s.	d.
One engine-driver	0	4	9
Two men	0	4	9
One horse and one boy	0	4	0
One pair bullocks and driver for carrying water and fuel ...	0	4	9
6cwt. 1qr. 6lbs. of coal (8·8 lbs. per horse-power hour for an engine of 8 horse-power working ten hours), at 18s. per ton	0	5	8
Oil, cotton-waste, putty, &c. ...	0	1	7
Total ...	1	5	6
Plus writing off wear and tear ...	1	7	4
Daily expenditure ...	£2	12	10

Which brings the cost of ploughing 1 acre to £3 7s. 5d.

B. Double-effect Plant.

Average cost, £600. This capital to be written off in the same number of years, and the same rate of interest. If we assume we plough 80 poles per day, and work 40 days in the year, we arrive at the following :—

	Per Annum. £	s.	d.
Writing off and interest at 5 per cent. of £600 in eight years	105	0	0
Wear and tear of material at 3 per cent. of the capital	18	0	0
Total	£123	0	0

Equal to £3 1s. 6d. per day.

The daily expenditure is reckoned as follows :—

	£	s.	d.
One engine-driver	0	4	9
Three workmen, at 2s. 4d.... ...	0	7	0
Pair bullocks and driver	0	4	9
7cwt. 3qrs. 14lbs. coal (8·8 lbs. per h.p. hour for a 10 h.p. engine working 10 hours), at 18s. per ton ...	0	7	0
Oil, cotton waste, putty, &c. ...	0	2	0
Total	1	5	6
Plus writing off wear and tear ...	3	1	6
Daily expenditure	£4	7	0

Which brings the cost of ploughing one acre to £3 9s. 7d.

We see that for a small grower who does not trench or subsoil more than 50 acres each year the simple-effect plant is more economical than the double effect. In order to derive advantage from the latter we must plough annually at least 72 acres; for an area of 70 acres, the cost is equal in both systems—£2 14s. 5d. per acre.

It is interesting to ascertain for what area yearly ploughed it is justifiable to use steam-power.

Assuming that we require two days to plough ½ acre with a horse-gin, and that the same work can be done by steam in ⅔ day, we see that for an area under 30 acres per annum the advantage lies on the side of the horse-gin, and for an area exceeding 30 acres it falls to the side of the steam-power. The cost of one acre in this case comes to £4 1s. 7d.

The advantages are in favour of steam power for a lesser area, if a portable engine is already in use for other work on the farm, and worked a greater number of days, as in this case the writing off of the capital and the wear and tear is spread over a greater number of days. This is generally the case.

Steam-power is therefore always cheaper when there is an engine on the farm.

Independently of the question of economy, which makes us favour steam-power applied to simple-effect in preference to double-effect capstans, we must also take the power of the engine into consideration. If it is under 8 H.P., it could not work, without stoppages, a plough working at a depth of 20 inches. With a simple-effect drum, the pressure is regained while the plough is being hauled back into position. The engine can, therefore, perform in an intermittent way, work that it could not do continuously.

In conclusion, experience teaches us that it is possible, with capstans driven either by steam or horse power, to do deep ploughing impossible with ordinary teams, and at a cost so much the less as the area to be ploughed is larger, and always at a cost below £4 16s. per acre.

For small growers who cannot spare the capital necessary for the purchase of the plant, and for those who do not possess an area large enough to justify the buying of such machinery, the hiring of it becomes advisable, and many contractors are nowadays ready to undertake the work at reasonable prices. Many are already at work, and it is to be hoped that this number will increase. They are called upon to render great services to small growers, especially in viticultural regions which have been unfortunately invaded by the phylloxera.

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II.

APPLIANCES FOR TRENCHING AND SUBSOILING.*

By Max Ringelmann,

Professor at the National Agricultural Institute, Paris.

At the beginning of the nineteenth century, agriculturists were convinced of the need of deep cultivation for the improvement of land for certain special cultures, that of madder for instance, but the difficulty of execution of deep ploughing resided in the defective making of trenching or subsoiling ploughs, as well as in the great number of animals required for this work. In 1852 the improvements made in iron implement construction generally, enabled Vallerand to initiate sugar-beet culture by disturbing the land to a depth of 14 inches, a depth which was very soon increased when the Bonnet plough appeared on the market. This improvement of the land tended to become general towards 1855, while active polemics took place between the partisans of trenching (bringing the subsoil to the surface) and those advocating subsoiling (disturbing the subsoil *in situ*). The latter had an advantage over the former in being able to use lighter implements, which it was easier to construct strongly at that time.

The manufacture of agricultural implements made very rapid advances between 1865 and 1880, owing to developments in the metallurgy of iron, and, above all, the substitution of steel for iron, enabled the construction of much more powerful instruments than that of Vallerand. A reaction then took place, the subsoilers were discarded, and the trenching plough gained the ascendancy.

Agriculturists were then in possession of powerful ploughs, but could rarely spare the necessary draught ; for this reason the use of these implements was very limited. The viticulturists of the South of France, convinced of the possibility of reconstituting their vineyards with American vines, and of the necessity of deep cultivation prior to planting these vines,

* *Journal d'Agriculture Pratique*, Vol. 64. 1900.

asked implement makers to devise a system which would enable them to perform deep cultivation with two to four animals only, during the slack season. Naturally, they were ready to give more time to the operation, this question being only of secondary importance, considering that a permanent improvement of the soil was required, and not a merely annual ploughing. Then in the year 1882 the construction of horse-gins applied to the hauling of ploughs was first attempted; a few years later these machines were used with success to clear and throw into culture Algerian plains, other colonies following this example.

To solve the problem, a motor, consisting of a capstan, was interposed between the plough and the team.

Any animal furnishes its maximum power when it is required to exert a certain effort F, at a certain rate V.

To give an example, we quote the following figures resulting from a large number of trials :—

Weight of the Animals.	Mean Effort Exerted.	Rate per Second.
	Horse.	
660 to 990 lbs. ...	143 to 154 lbs. ...	27·5in. to 29·5in.
990 to 1,320 lbs. ...	198 to 242 lbs. ...	25·5in. to 27·5in.
1,320 to 1,760 lbs. ...	264 to 330 lbs. ...	23·6in. to 25·5in.
	Bullock.	
550 to 880 lbs. ...	121 to 154 lbs. ...	27·5in. to 29·5in.
880 to 1,110 lbs. ...	198 to 242 lbs. ...	23·6in. to 25·5in.
1,110 to 1,540 lbs. ...	352 to 440 lbs. ...	19·6in. to 21·5in.

These figures correspond to a period of useful work of 45 minutes per hour, and an average duration of eight hours' work per day (360 to 400 minutes per day). When several animals are yoked together the mean effort diminishes, for the animals never pull simultaneously. The walking pace we may represent by the following figures, the useful effort furnished by each animal when yoked together with others*:—

* As an example of this in practice, let us assume a horse working alone furnishing a mean effort of 198 lbs.; the effort of a pair will then be 198 × 2 × 0·93 = 368·2 lbs. The effort of four animals working abreast will be 367·4 lbs. × 2 × 0·93 = 683·3 lbs., while if the animals are yoked in tandem we will only have 198 lbs. × 4 × 0·75 = 594 lbs. Assuming a bullock exerting a mean effort of 220 lbs., two bullocks abreast will give 220 lbs. × 2 × 0·93 = 409·2 lbs.; two pairs will furnish a mean effort of 409·2 lbs. × 2 × 0·93 = 761 lbs.

Number of animals per team.	Useful effort exerted by each animal (ratio).
1	1·00
2	0·93
3	0·85
4	0·77
5	0·70
6	0·63
7	0·56
8	0·49

Animals furnish per second mechanical work T given by the formula:—

$$T = FV.$$

But we cannot compel them to give us *equivalent mechanical work** as, for instance, to furnish us with an effort three times greater with three times less speed. In other words, we cannot apply the following formula:—

$$FV = 3F\frac{V}{3} = 10F\frac{V}{10} = \ldots\ldots$$

which is possible with other motors. For one must observe a relation between the frequence of the movements of the skeleton and those of the movements of the heart; thus, a man having sixteen respiratory movements per minute, can only work a handle at the rate of 16, 32, 48, 56 revolutions per minute, or strike 8, 16, 24, 32 blows with a hammer. Experience shows that when this concordance is not observed, breathlessness occurs, the animated motor becomes fatigued and quickly succumbs.

In the application we are considering now, the resistance of the implement is diminished by means of an intermediate mechanism, in order to work the animal at its most favorable speed. This mechanism will absorb a part of the effort for its own work.

If k is the yield of the mechanism,
F the effort of the animal,
V its mean speed,
n a fixed co-efficient, greater than unity, we may write:—

$$FV\,k = nF\frac{V}{n}.$$

* See *Traité de mécanique expérimentale*, p. 141; Librairie Agricole.

nF is the resistance to be overcome, that is to say the traction of the plough which we may designate as R;

$\frac{V}{n}$ is the speed of this resistance, which we may designate by v, and we may write :—

$$FV\,k = R\,v.$$

Let us notice that we lose a certain quantity of motive power F × V, for the co-efficient k is less than unity, but the intermediate mechanism offers the enormous practical advantage of enabling us to obtain, with the most advantageous speed of the animal, a traction R of the plough as high as is desired, on the condition, however, of diminishing the speed v of the latter proportionately. We may recall the popular expression—"*What is gained in power is lost in speed.*"

The mechanism used may be a gearing winding drum or a capstan.

According to Ferrouillat, Desforges relates.* (See page 18.)

J. C. Loudon (*Encyclopedia of Agriculture*, 1831) mentions a mole-plough invented by Adam Scott, and improved by Lumbert, of Gloucestershire ; this implement, penetrating very deeply into the soil, was hauled by a capstan worked by four men or by a horse.

The capstan was improved by Weir, of Oxford-street, London. The figure in Loudon's work gives a fairly accurate idea of those in actual use.† We give, on account of its historical interest, the Fig. 29, which shows one of these capstans hauling a mole-plough.

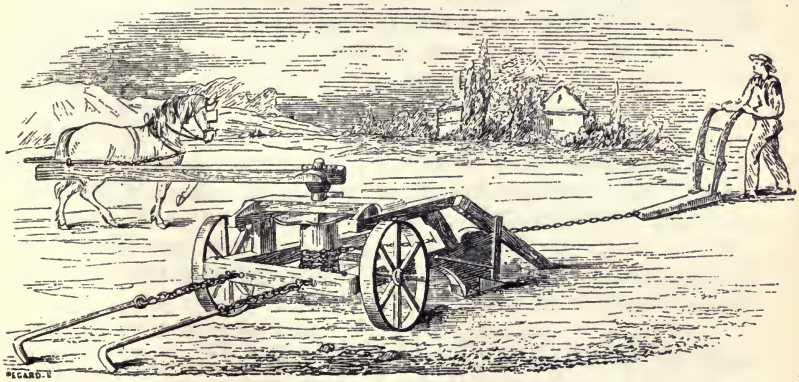


Fig. 29.—Lumbert's Mole-plough.

* *Rapport sur le concours special de treuils à Narbonne*, 1888.

† See *Loudon's Encyclopedia of Agriculture*, 8th edition, 1883, page 401.

De Gasparin* mentions the plough (Fig. 30) and capstan of Bierley, travelling at a speed of 1·36 in. per second, under a hauling traction of 13 cwt. 3 qrs. The

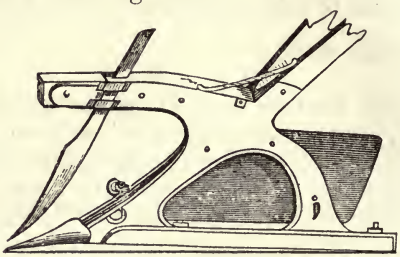


Fig. 30.—Bierley's Plough.

plough was reduced to its simplest form, the wire cable being fastened to the front of the body. De Gasparin says:—"We have also seen ploughs and capstans used for the uprooting of madder; a donkey or a weak horse opened a furrow, which would have needed a team of 24 horses; a cable winding round a drum increased the force of the traction, but proportionately increased the time necessary to perform the work. A furrow of 526 feet only was opened in one hour, and after each furrow a great deal of time was wasted in returning the plough to the starting point. The cost was half that done by hand, but four days were required to plough 1 acre, which 24 horses would have ploughed in twelve hours for the same cost.

"In 1841 Georges worked a horse-gin with a Dombasle plough. He is reported to have ploughed three parallel furrows 52 feet in length, 8½ inches in width and depth, in eighteen minutes. Six men worked the capstan alternately; it was 4ft. 11in. in diameter; the men worked levers 10ft. 9in. in length. The resistance of the plough must have been 454 lbs., equivalent to four ordinary horses, which could have ploughed ¾ acre in eight hours.† To estimate the cost of the two operations it suffices to compare 32 hours for one horse, as against 372 hours for one man. But if, instead of six men, one horse had been used, we see that the mechanism of the capstan would have caused a loss of half the strength used."

De Gasparin only studied this system as applied to yearly cultural operations, and not from the point of view of the permanent improvement of the land, which explains his inference.

* *Cours d'Agriculture*, vol. iii., p. 155.
† Laur, *Culture de la Garance*.

In England various capstans have been used for drainage (Pearson's system worked by hand),* amongst which we may mention Fowler and Fry's machine.† Fig. 31 shows Fowler

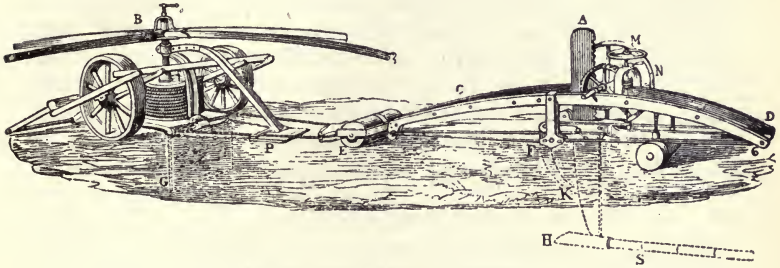


Fig. 31.—Fowler and Fry's machine.

and Fry's capstan B and their mole-plough A, which are not within the scope of the present study. The capstan being anchored to plate G, and resting on a shoe P, two to four horses are yoked to it. In 1855 Fowler used a 6 to 8 H.P. engine to work this capstan, and an official trial of it was made on the 7th June, 1856, near the Trianon (Paris), in presence of an international jury.

Trenching and subsoiling with the aid of a steam-winding drum was undertaken near Gand in 1877, with a view of applying them to the stiff soils (polders of Zealand).‡

After these few attempts, capstans seem to have been forgotten, till the reconstitution of vineyards in the South of France reintroduced the question of deep ploughing. At first the ploughs were hauled by teams of often more than ten horses, then hauling engines were used (Fowler), but these were too costly to come into general use, and vine-growers were on the look-out for a system to enable them to economically trench or subsoil small areas.

In 1876 Léonce Grué, of Beaulieu, near Solliès-Pont (Var), used a horse-gin worked by two horses, formed of a winding drum, hauling the plough by means of a steel rope. Bourguignon following his idea, constructed the Valessie system in 1887.§

While the South of France was greatly preoccupied by the reconstitution of their vineyards and the deep cultivation

* *Trans. of the Soc. Arts*, 1829. Pearson's method of pipe draining.

† *Rapport général de Pusey, sur les instruments agricoles à l'exposition universelle de Londres*, 1851.

‡ *Défoncements et sous-solages à vapeur.* G. Scribe ; *Journal d'Agriculture pratique*, 1877, vol. 1. p. 829.

§ Bourguignon constructed the first capstan of Grué.

necessitated, our colleague, P. Ferrouillat, then Professor of Agricultural Engineering at the National School of Agriculture, Montpellier, expressed the following views in the Progrès Agricole of 1891 (see page 63).

In 1888, a special competitive show of capstans was held at Narbonne. More than one hundred were then in use in the South of France for the preparation of land for reconstitution purposes. In 1890 another competitive show was held at Perpignan. The widespread use of these machines in the South of France and Algeria dates from that time.

Horse-gins.

Horse-gins* consist essentially of a drum or cylinder, A (Fig. 32), revolving round a vertical axle *a*. The horse M is yoked at the end of a pole L, to which the bridle is

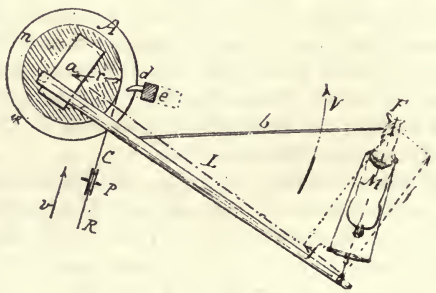


Fig. 32.—Diagram of a Horse-gin.

also connected by a wooden rod *b*. When the pole is clamped on the drum by means of cotters or pins the horse in his movement revolves the drum which winds the cable C, at the extremity of which the plough is fastened. The motor M, exerts a mean effort F, a part of which *f*, only is utilized; the latter being the projection of the effort F on the perpendicular to the radius passing by the yoking hook,† the other component *f'*, simply increases the pressure of the drum on its axle. It is, therefore, advisable to diminish *f'* (prejudicial force), and increase *f* (useful force), by giving the greatest possible length to the pole. In practice it does not exceed 16½ feet.

For heavy work, instead of using a single horse, two or six may be yoked to corresponding poles fixed in the socket

* In mechanics, in the study of *simple machines* a wheel revolving round a vertical axle (as we are studying here) is called a capstan. We will, however, use the word gin, which is now accepted in practice. [Trans.]

† See *Traité de mécanique expérimentale*, p. 112.

head, which is clamped on to the drum at will. If we only have small horses at disposal, they may be yoked in pairs to each pole.

The drum A (Fig. 32), is generally made of cast iron, with flanges *n* at least 6 inches wide. These flanges are often cast together with the drum, or made of wood (Beauquesne) or steel (Bajac). It is important to prevent the cable from getting caught under the bottom flange. For this purpose a guide is fixed on an upright *e*, or the bottom flange is enveloped by a ring, the upper brim of which is level with the plane of the flange (Pelous). Accidents oftener occur when the rope is unwinding, and to avoid them the drum must be steadied by means of a brake.

To render the winding of the cable as regular as possible, it is advisable to place a runner P at a distance of about 6 feet from the axis of the capstan (Fig. 32), the height of which is level with the middle of the generatrix of the drum A. On account of the slow rate of the cable the various systems of automatic winding have been discarded. These devices were similar to those used in steam ploughing, where they are rendered necessary on account of the great speed of the cable.

To facilitate the stepping of the animals over the cable, it is advisable to have it passing as close as possible to the ground, this necessitates the use of very shallow drums, and also assists in increasing the stability.

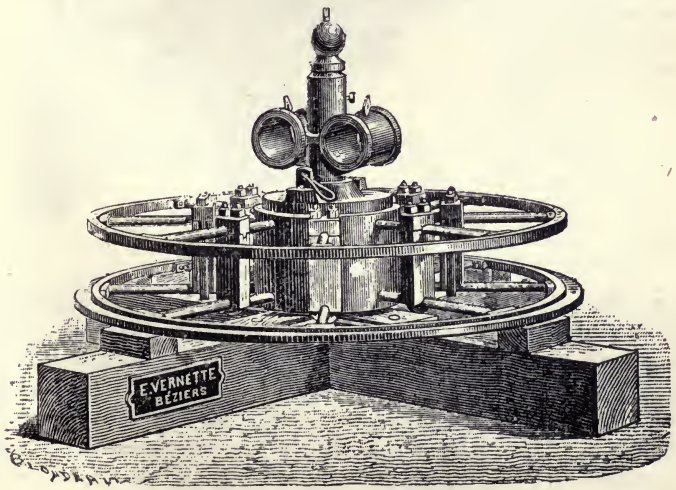


Fig. 33.—Vernette's Horse-gin, with Variable Diameter.

Generally the pole L (Fig. 32), has a constant length 11ft. 6in. to 16ft. 5in., and, according to the resistance R of the soil or the depth of ploughing, the speed, v of the plough is modified, the speed V of the motive power remaining unaltered. This is obtained by increasing or diminishing the radius r of the drum. This is often done by inserting wooden sectors, varying in width, which have also the advantage of diminishing the wear of the cable (Beauquesne). Extensible mechanisms are also in use (Vernette, 1894); the radius of the drum may by this means be varied from 12 inches to 20 inches. Finally, we may use a toothed gearing.

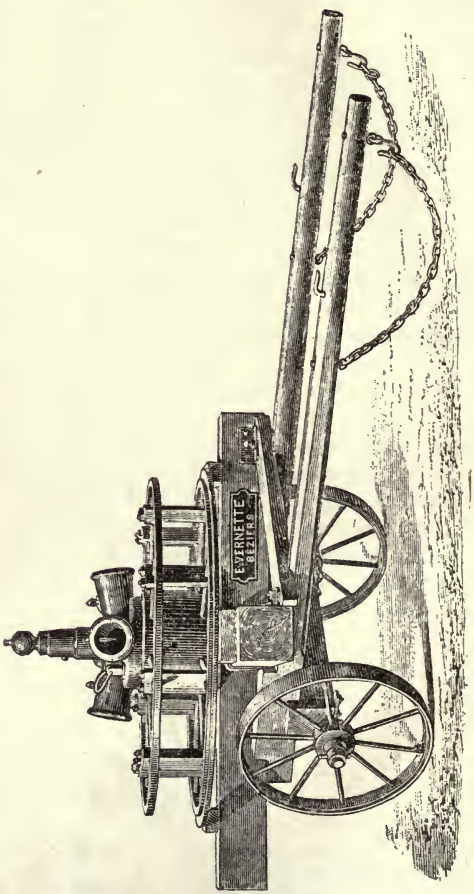


Fig. 34.—Vernette's Horse-gin, 1 test pattern.

In Vernette's gins (Figs. 33 and 34) the drum is made of two horizontal wheels, on the spokes of which cross-pieces may slide, making a skeleton drum of variable diameter limited by eight generatrices, kept in place by iron straps bolted at the top. The diameter of this drum may vary from between 20 inches to 5 feet. One revolution of the capstan corresponds, therefore, to a movement of the plough of from 5 feet to 16ft. 6in.

To enable the rate of translation of the cable to be varied, Léonce Grué modified his machine of 1876, and designed, under the name of Beaulieu-gin, a machine with cog-wheels, a diagram of which is shown in Fig. 35. (See for description, page 27.)

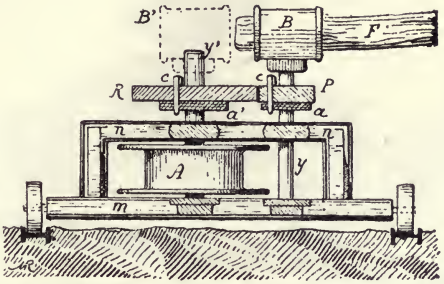


Fig. 35.—Diagram of the Beaulieu-gin, constructed by Grué.

According to models, the drum is fixed on a vertical shaft, the bottom of which revolves in a cup-socket fixed in the centre of the bed-plate, the top in a collar held in a frame or *bridge*, above which the pole-socket is fixed—Fondeur, Guyot (Fig. 16, page 37), Pelous (Fig. 36), Bourguignon, Valessie,

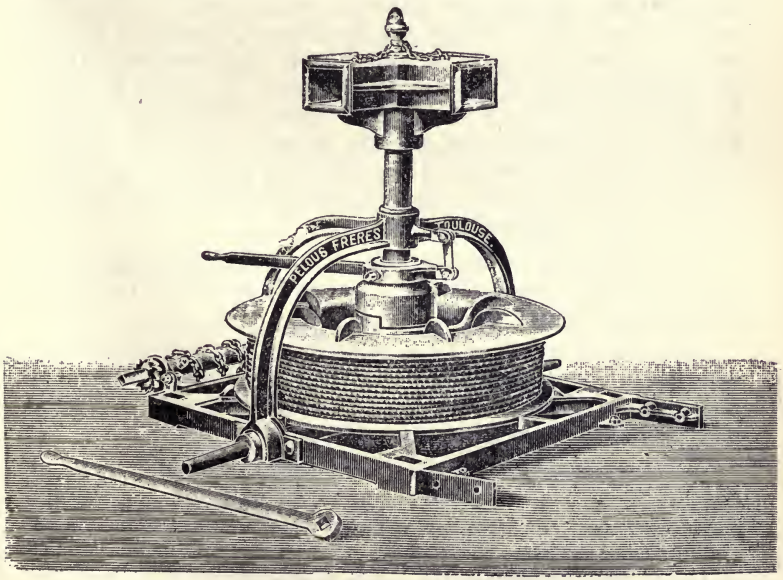


Fig. 36.—Pelous' Horse-gin.

Bajac (Fig. 37). It seems preferable to fix a pivot on the bed-plate round which the drum and socket-head revolve, Vernette (Fig. 33). Such was the system adopted by Beauquesne. During work the socket-head is clamped on the drum by a

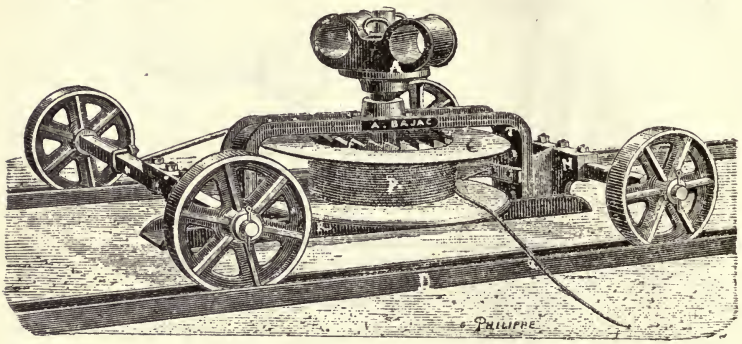


Fig. 37.—Bajac's Horse-gin.

coupling clutch, cotters or pawl, each of which may be seen in the above figures. While the plough is being taken back the drum is thrown out of gear, and the horses rested.

According to the system, the gin is either displaced before each furrow; in this case it travels on four rollers (Fig. 37), or on a bed-plate sliding on the ground, Guyot (Fig. 16, page 37) Fondeur, or it is placed in a fixed position during the whole ploughing (Figs. 33 and 35). It is kept in place by means of pegs or surcharge (Pelous). When the work is finished, the travelling of the gin is facilitated by a special frame mounted on wheels (Fig. 34), very often the bed-plate itself is provided with axles on the arms of which wheels may be fitted (Pelous, Fig. 36).

The drums are built to wind from 219 to 274 yards of cable, which is made of the best steel wire, varying from 0·5 inch to 0·6 inch in diameter.

The mechanical yield of simple-effect drums, without cog-wheels, is very high. B. Chabaneix, of the School of Agriculture, Montpellier, made trials in August, 1887, the results of which are given on page 43.

We may admit in practice that the mechanical yield of simple-effect gins varies between 80 and 85 per cent., according to the lubrication of the axles which bear enormous pressures, the length of the poles and the diameter of the drum (rigidity of the cable opposing the winding).

When the cable drags on the ground it creates a supplementary resistance. The weight of the cable is usually 8 ounces per foot, the co-efficient of friction being 0·6. Under these conditions the additional effort of traction is 0·48 ounce per foot of cable. If we assume a furrow 274 yards in length, the additional effort mentioned above at the maximum is:—

231	lbs.	when the plough is	274	yards	distant.
184·8	„	„	219	„	„
92·4	„	„	109	„	„
9·24	„	„	33	feet	„

But in practice it is not necessary to have a greater effort at the beginning of the furrow than at the end, for the cable winding round the drum increases the diameter, and therefore the leverage as the work proceeds. Finally, we have noticed the enormous traction exerted on the cable diminishes its pressure on the ground, and therefore its friction.

The ratio between the speed of the end of the pole, and the speed of the plough, varies between $\frac{6}{1}$ and $\frac{20}{1}$; the ratio usually worked at is $\frac{10}{1}$.

With the above data it is easy to calculate the effort of traction exerted on the plough.

Assuming a ratio of speed of 10 to 1.

A team of four horses, each capable of developing a traction of 220 lbs.

A mechanical yield of the machine of 85 per cent., we find:—

Mean effort of the team:

$$220 \times 4 \times 0{\cdot}77 = 677 \text{ lbs.}$$

Mean effort exerted on the plough:

$$677 \times 10 \times 0{\cdot}85 = 5{,}674 \text{ lbs.}$$

This applies only to simple-effect drums.

INSTALLATION OF TRENCHING OR SUBSOILING PLANT.

Simple-Effect Capstans.

The installation of such plant is to be considered according to whether—

1st. The capstan is displacing or not;

2nd. The hauling back of the plough takes place with a special team (one horse or two bullocks), or with an additional mechanism on the capstan;

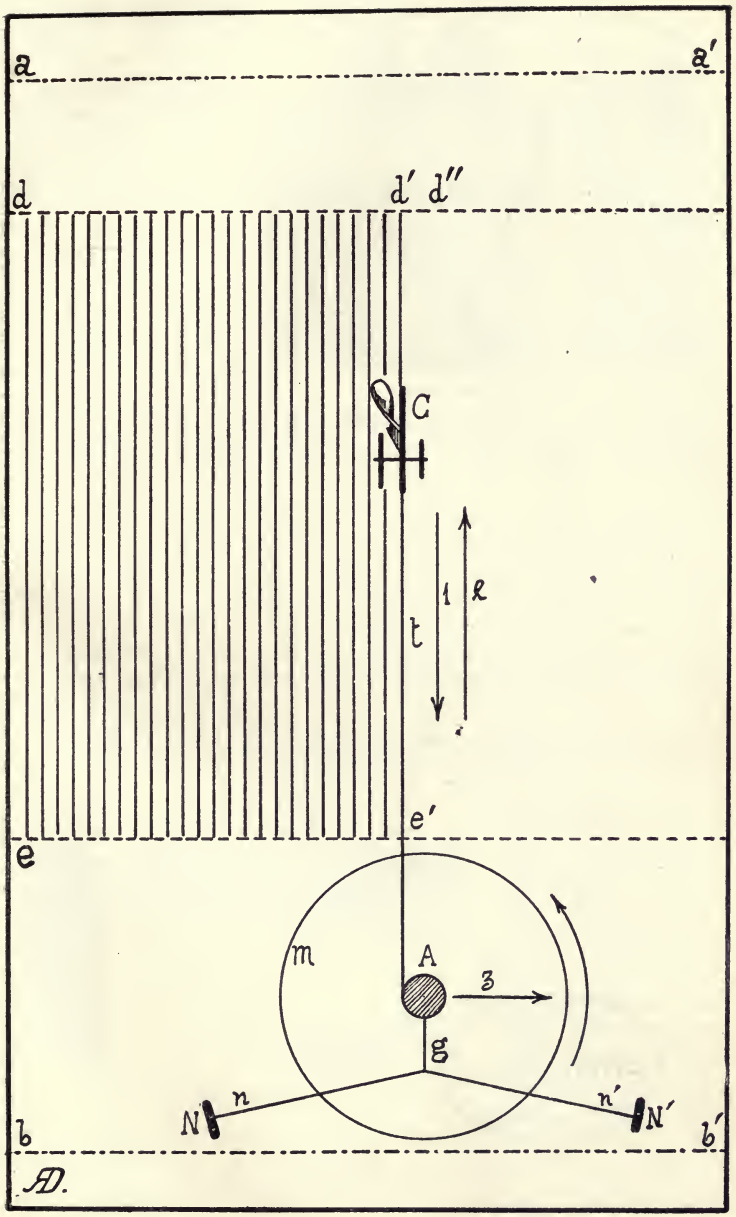
3rd. The work is done in one direction with the plough turning the sod on one side only, or in both directions with a turn-wrest or balance plough.

When the capstan is displaced for each furrow the traction is said to be direct. In this case (Plate I.), the capstan A is installed on one of the headlands *b b'*, the cable *t* hauling the plough C in the direction of arrow 1. At the start the plough is at *d'*, it opens a furrow *d' e'*, when it reaches *e'* the drum A is disconnected, the plough C taken back to *d''* in the direction of arrow 2, the cable unwinding. During this operation the horses rest and the capstan is moved a distance equal to the width of the sod in the direction of arrow 3.

With this installation, the width of the non-ploughed headland *a a'* is reduced to 9ft. 10in., while that of the headland *b b'* is equal to the diameter of the track *m* that is to say, 32 feet to 38 feet. An area *d d' e e'* smaller than the block, is ploughed that way, the two headlands *a a' b b'* being ploughed in the direction of arrow 3.

This installation, which dispenses with the fixed pulley and reduces the length of the cable (as compared with other systems) has the drawback of leaving on the capstan-side a wide headland tramped by the horses.

The displacement of the capstan A (Plate I.), in the direction of arrow 3, may be done in two different ways; the drum is fixed to a bed-plate, fastened to a chain *n g n'* secured to two anchors N N', or may travel laterally on rails.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In the first case, a beam N (Fig. 38), 8ft. 6in. × 4ft. 3in. in section, and 3ft. 3in. at least in length, is buried in a trench 12 inches deep; behind this beam, and in a slanting direction, two pegs *p* are driven into the ground, in such a manner that the points be further apart than the heads, a gudgeon B passed through a ring of the chain *n*, rests behind the pegs, the traction of the chain being rendered even on the beam N.

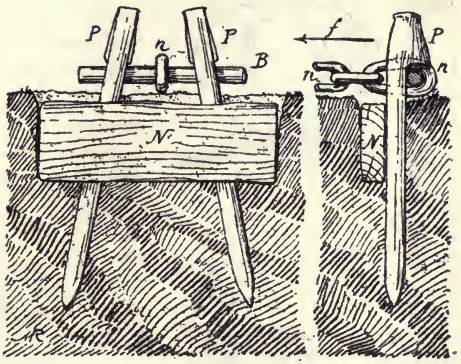


Fig. 38.—Anchoring Beam.

If we study Plate I. again, we see that when working, the capstan A exerts a traction on *g* in the direction of arrow 2, equal to the sum of the resistances of the plough C and the cable *t*. This traction is divided on the two pieces *g n* and *g n'* of the chain *n n'*, the result being a tendency to bring the anchors N and N' closer together, exerting a compressing action on the soil, which under these conditions offers great resistance.

Certain implement makers replace the beam by a wrought-iron plate, the principle remaining the same.

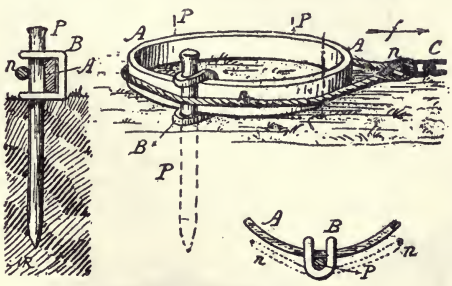


Fig. 39.—Guyot's Anchor.

Guyot now uses the anchor shown in Fig. 39, consisting of a steel ring A lying flat on the ground, and kept in place by four pegs P strapped on the ring at B, the traction chain C passes over the ring. With this arrangement the pegs blocked by the straps cannot lean, and offer great resistance to the traction *f* without requiring the ramming of the soil necessary when using a beam. (Price of anchors and

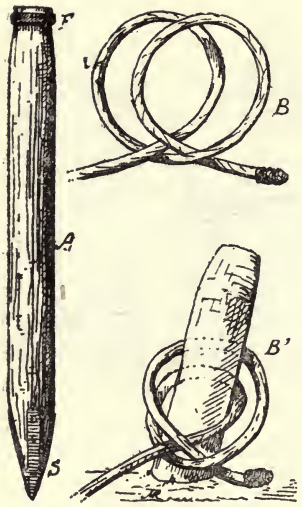


Fig. 40.—Anchoring peg and clove-hitch knot.

3in.; E, 2ft. The knot used to fasten the ropes to the pegs is the *clove-hitch* (shown in Fig. 40), or the *anchor bend*, which is still stronger

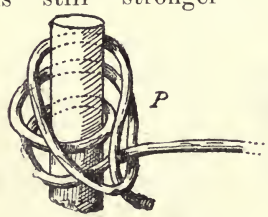


Fig. 42.—Anchor bend.

case the chain *g* is made fast to it by a gripper (Fig. 44). It is comprised of two jaws *a b* turning round a pivot *o*, fixed to a plate *m*,

chain, £5.) We may also adopt the mode of pegging used by military engineers. The pegs A (Fig. 40), are made of pine wood, they are $3\frac{1}{2}$ to $4\frac{3}{4}$ inches in diameter, terminated by a square point, provided with an iron shoe S, the other end furnished with an iron hoop F. At the foot of the peg A (Fig. 41), the anchoring cable T is fastened level with, or slightly below the surface of the soil; this peg is driven in a slanting direction to a depth of between $15\frac{1}{2}$ to $19\frac{1}{2}$ inches, its head *b* is joined to the foot of the peg B, driven 6ft. 6in. distant from it, and so forth, for the pegs, C, D, E. The length of the peg A is 5ft. 9in.; B, 5ft. 3in.; C, 4ft. 6in.; D, 3ft.

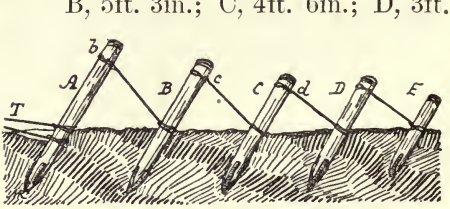


Fig. 41.—Mode of anchoring.

(Fig. 42). The cable *T* is fastened to the peg A, by two *half-hitches* (Fig. 43). The two anchors N N (Plate I.), are joined by a chain, *n n'*, 32ft. 10in. in length, to one of the links of which the chain *g* is hooked. The chain *n n'* is sometimes replaced by a steel wire cable of 0·6-inch in diameter. In this

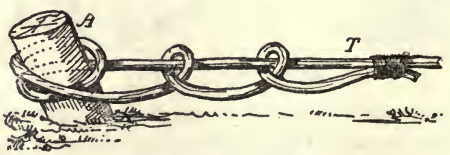


Fig. 43.—Half-hitches.

in which the cable is caught; the levers *a* and *b* are joined by the rings *c* and *d* to the chain *g*. Under the effect of the traction the cable is gripped at *m*.

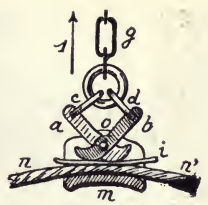


Fig. 44.—Automatic Gripper.

To displace the capstan A (Plate I.), in the direction of arrow 3, the cable *g* must be slackened; this is done sometimes by hand with a crowbar, or with a special device (Fondeur and Pelous, Fig. 47), serving to haul it back. In other systems it is done by horses (Fig. 45). To displace the capstan in the direction of arrow 1 a small chain *a a'* passing over a pulley P fixed on the chain *n n'* is fastened to the pole by a hook. When the horses pull in the direction of arrow 2, the chain *g g'* is slackened; the horses are backed, the chain *a* unhooked from the pole L, and the point of traction *g* shifted a distance equal to the width of the sod to be turned.

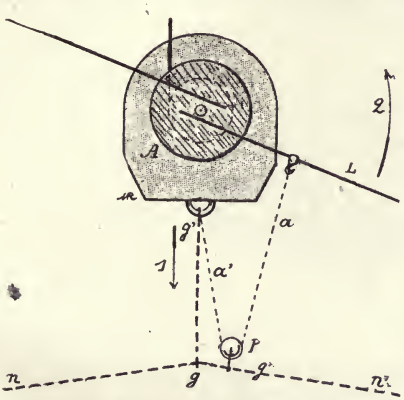


Fig. 45.—Diagram showing how the Capstan is Displaced.

To facilitate these different operations, several implement makers mount the capstan on four rollers travelling on rails.* The rails are made of iron rolled joist girders, as used in structures (T Fig. 46), lying flat on the previously levelled ground.

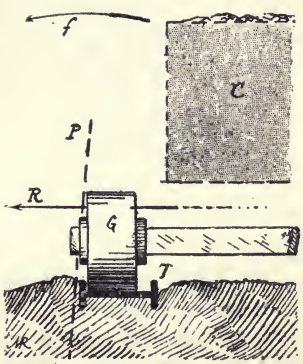


Fig. 46.—Diagram showing the Position of Rollers on Girder.

The traction R exerted on the rollers resting against one of the flanges is equilibrated by the resistance of this beam gripping in the ground; this is why it is preferable to sink the beam in the

* In 1889 H. Beauquesne (*Journal d'Agriculture Pratique*, Vol. I., p. 460), mentioned this device as having been applied before by Grué, Valessie, and several others.

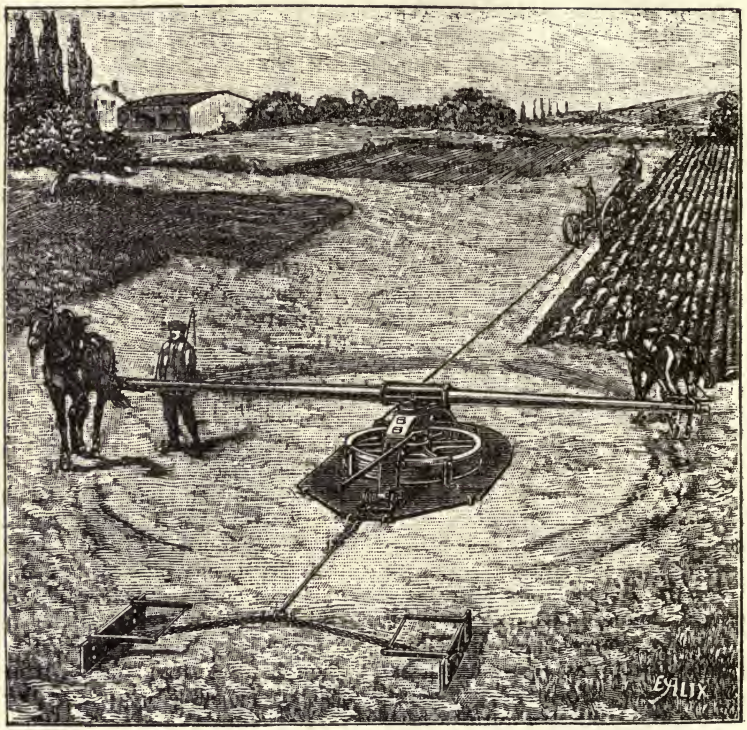


Fig. 47.—Fondeur's Plant.

ground throughout its length. This operation is easy when the ground is slightly damp, for the penetration takes place of itself. If not, it is necessary to drive pegs P in a slanting direction, or to increase the weight of the system by cases C filled with earth. Finally, to prevent the rollers from becoming derailed, the cable must be kept as close as possible to the ground. If not the machine has a tendency to tilt over in the direction of the arrow *f*.

With such an installation four girders only are necessary, alternately displacing each pair.

With the object of dispensing with the horse and boy required for hauling the plough back, implement makers construct capstans provided with an additional mechanism which does the work. This device is undoubtedly handy when steam is used, but complicates the horse-gin unnecessarily. The cable used is 0·35 to 0·39 inch in diameter.

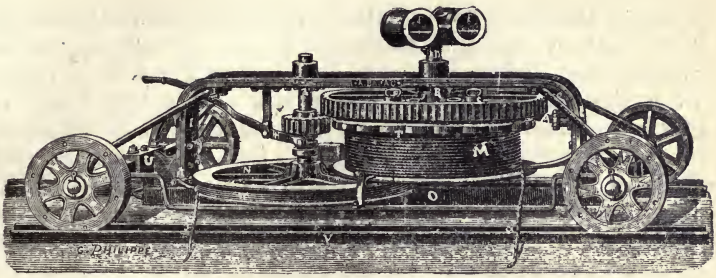


Fig. 48.– Bajac's compound Horse-gin.

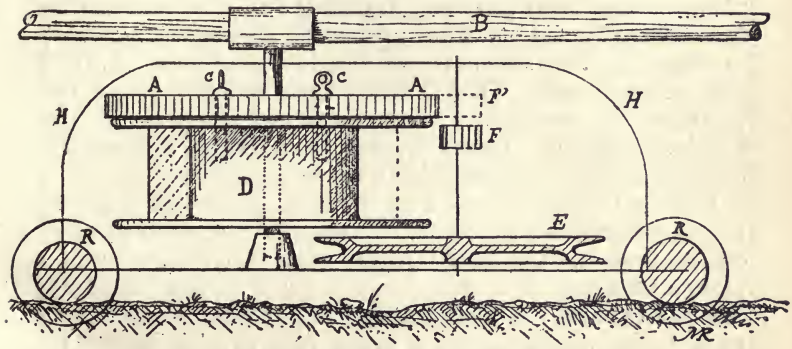


Fig. 49.—Diagrammatic section of same.

In Bajac's gin (Agricultural Show of 1892), shown in Figs. 48 and 49, and Plate II., the large cog-wheel A connected with the pole B, can be clamped to the drum D by means of two pins *c*. The hauling-back cable winds on the groove of the pulley E connected with the pinion F, which engages the cog-wheel A, when the drum is thrown out of gear; the pinion F is worked by a lever shown in Fig. 48, in which may also be noticed the pawl clicking with a ratchet on the top flange during the work. When the plough reaches the end of a furrow the drum *d* is released, the pulley E thrown into gear, the hauling back cable passing over the fixed pulley and winding round it, pulls the plough back to the start; the horses always turn in the same direction. According to the stiffness of the soil, the diameter of the drum may be increased by wooden sectors, as shown in Fig. 49.

The whole mechanism is carried in a strong frame, travelling on four discs with a sharp edge, penetrating the soil, as shown in Fig. 49, or by rollers on rails (Fig. 48).

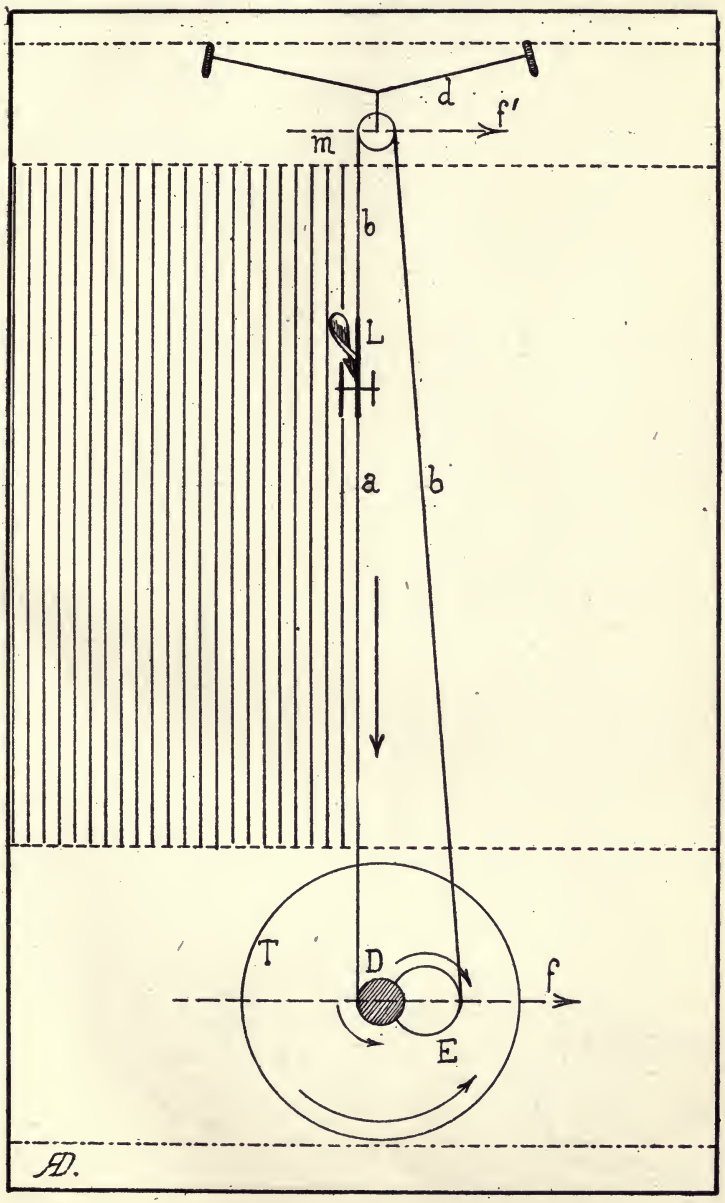
Plate II. shows the installation of the plant in the block; the traction cable *a* fastened to the plough L, winds round the drum D; the hauling-back cable *b* passes over the fixed pulley *m* and winds round the drum E. After each furrow has been turned, the system is displaced in the direction of the arrow *f*, by an additional small capstan, or on rails. The pulley *m* is displaced in the direction of the arrow *f'*, for a distance equal to the width of the sod. The pulley *m* is fixed by a chain *d* stretched between two anchors.

With the object of ploughing both ways with a balance-plough, it has been proposed to install two gins, one on each headland (Plate III.). The horses work alternately, as shown in Fig. 50, but the part unploughed measures 32 to 39 feet on each side. This arrangement, which requires two machines, is convenient when one cannot spare much time for the operation. Under favorable conditions, it is possible to plough ½ acre per day with such an installation.

It does not, however, do more work per horse per day. Let us consider the following figures resulting from personal observations in the field: A gin with two horses hauls a plough at a rate of 2 inches per second, turning a sod 21½ inches wide and 15½ inches deep; the hauling back is done by a horse travelling at a mean rate of 19½ inches per second. Assuming a length of furrow of 219 yards we arrive at the following conclusions :—

	System with—	
	1 Capstan.	2 Capstans.
Number of horses yoked to the capstan...	2	4
" " for hauling back ...	1	0
Total	3	4
Time required to open one furrow:		
Working forward	67 seconds	67 seconds
Throwing the plough out, disconnecting the drum	2 "	0 "
Hauling back	7 "	0 "
Starting the plough...	3 "	0 "
Balancing and starting the plough ...	0 "	5 "
Total per furrow	79 "	72 "
Actual work done per hour:		
Length of furrow	166 feet	180 feet
Surface ploughed (in square yards) ...	99 yds.	108 yds.
Surface ploughed per horse and per hour (in square yards)	32 "	27½ "

The difference is quite as marked if four horses are used and the speed of the plough greater.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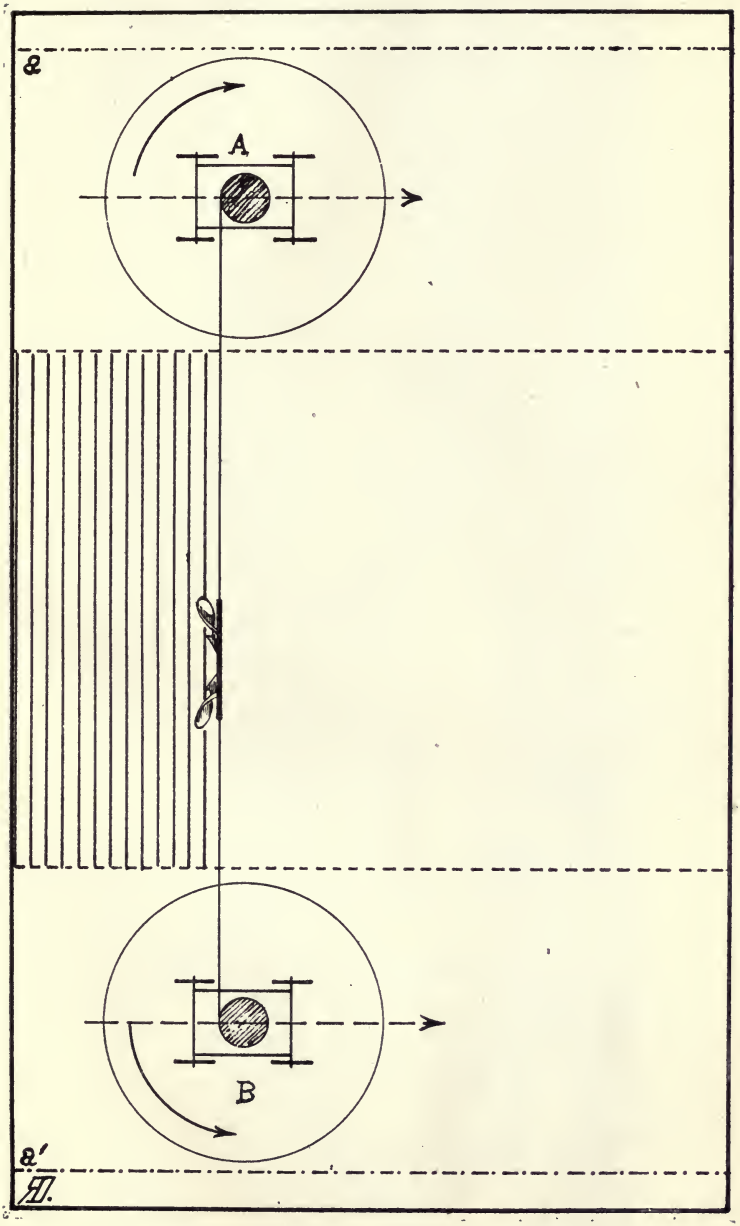
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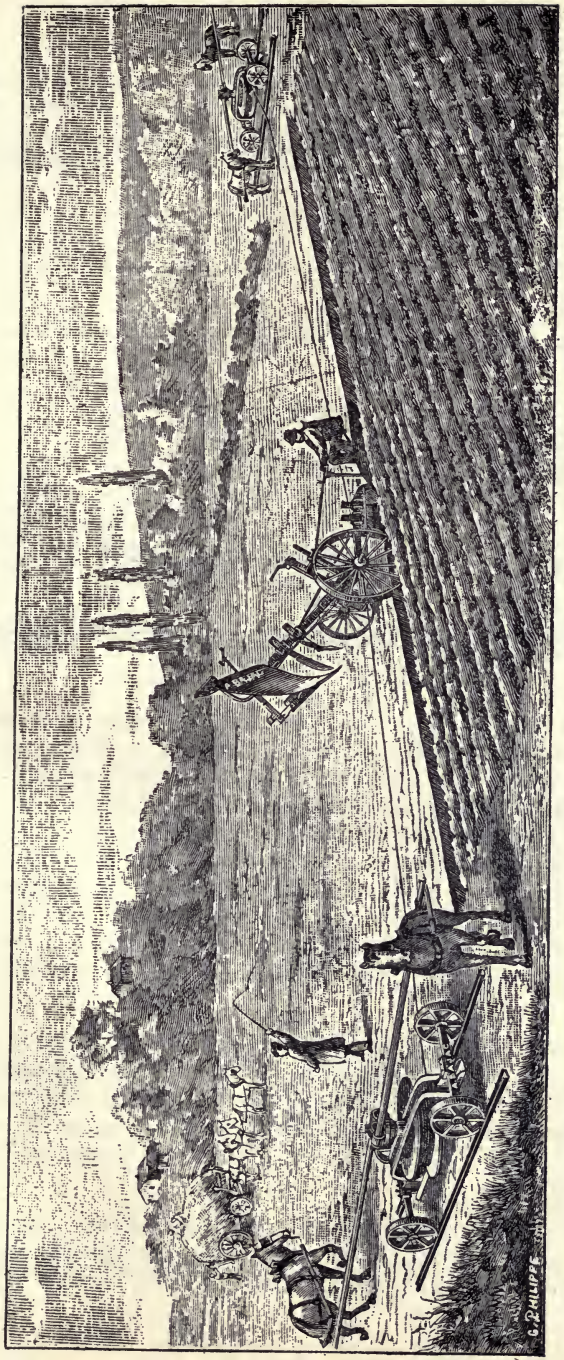


Fig. 50.—The Double-gin System.

Double-effect Capstans.

Finally, with the object of doing more work with one capstan, balance-ploughs, ploughing both ways, have been tried. In this class we may mention Debains' system, exhibited by Tritschler at the general annual show held at Paris, 1892.

Diagram 51 and Plate IV. show the capstan A, with two bevel-pinions B and C, gearing together, and on the horizontal shaft a coupling-clutch *d* allowing the drums E and F to be

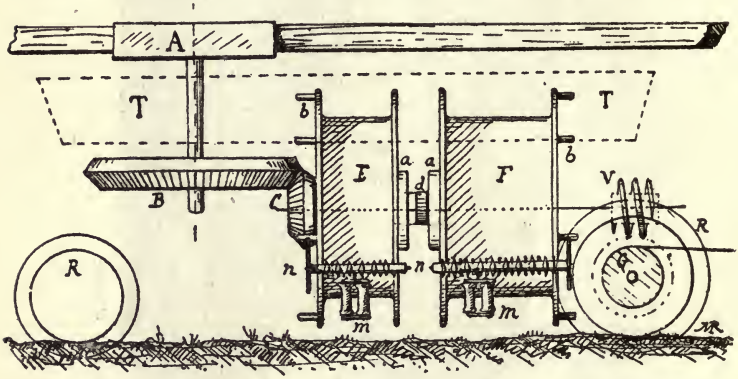
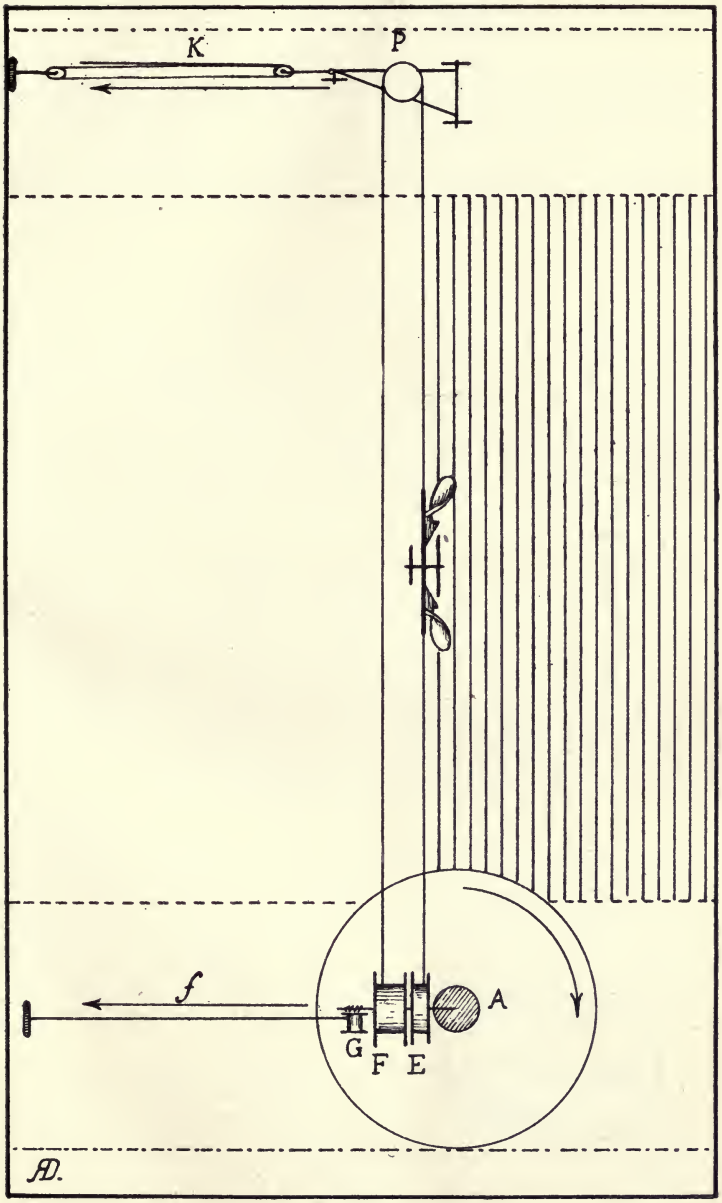


Fig. 51.—Diagram of Debains' compound system.

engaged alternately. The two drums are equal in diameter, but of different width. On the drum E, a direct traction cable winds which is fastened to the balance-plough. On the drum F, which is double the width of E, the hauling-back cable double the length is wound. Brakes act on the flanges *a a* to steady the unwinding ; two winding guides *n n* revolve on a horizontal axis, on which two spirals are fixed, wound in opposite directions, forcing the guides *m m* to travel right and left alternately ; each spiral is worked periodically by the pins *b* fixed on the flanges of each drum.

Debains' machine is mounted on four iron discs penetrating the soil and acting as anchors. The front axle is fixed by a king-bolt, enabling the machine to be turned; a small capstan G gearing with an endless screw B serves for the lateral displacement. A case T may be loaded with earth.

Plate IV. shows the projection plan of the system at work. The capstan A, the drum F, the plough M, the fixed pulley P, and its automatic anchor, provided with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three wheels, displaced by the block and tackle K, are shown in position. The additional capstan G is anchored to a fixed point by the chain *f*.

Machines such as that above described, with complicated mechanism and smaller mechanical yield than simple-effect capstans, require frequent stoppages in course of work in order to rest the animals. In conclusion, the use of balance-ploughs is of no practical benefit when horses are used.

Stationary Winding Drums.

When the capstan has to be displaced before every furrow, time is wasted, not only in ploughing the wide headland on which the machine is displaced, but the horses become also very tired through not travelling on a beaten track, having to walk on new ground after every displacement. The whole machine has also to be moved while the plough is hauled back. In 1888 the advantage of using a longer cable, a fixed pulley and a stationary capstan was recognised. The capstan may be stationed in the centre of the block if it is large enough (25 to 37½ acres), or in a corner of the block if smaller. With this arrangement a certain amount of mechanical power is lost* but this loss is relatively small, and is compensated by the facility of the execution of the work, and by the diminution of the width of one of the headlands, but we will see that the anchoring of the fixed pulley requires to be done with the greatest care, and, very often, it cannot be anchored at all in loose, soft ground.

The installation of the complete plant in working order is shown in Plate V. In one of the corners of the block, *a a'*, *b b'* (or outside if possible), the capstan A is strongly bedded. The traction cable *t* fixed to the plough C passes over the fixed pulley P anchored in *n n'*, hauling the plough in the direction of arrow 1, and is hauled back in position in the direction of arrow 2. With such an arrangement,

* To give an idea of the mechanical power lost, we quote the following figures :—A traction cable 109 yards long, sliding on the ground with a speed of 3·94 inches per second, requires 4 to 5 kilogrammetres per second. A fixed pulley 31½ inches in diameter, mounted on an axle 2·3 inches in diameter, over which a cable passes exerting a traction of 3 tons (resistance of a very powerful trenching plough) requires 67 to 68 kilogrammetres per revolution. The addition of a fixed pulley absorbs an average of 8 to 10 per cent. of the traction power of the cable.

the width of the headlands *f f'* may be reduced to a minimum. When the pulley P is very far away from the capstan A, it is advisable to use fixed runners *x;* these will be studied later on. Plate VI. shows diagrammatically the arrangement for trenching or subsoiling a large block *a b c d*; the capstan A is stationed in the centre of the block, which is divided into four sections, *e a f* A, A *f b g*, A *g e h*, *e* A *h d*, ploughed in the direction of the arrows using a fixed pulley *u*. The headlands are also ploughed without moving the capstan, in the direction shown by arrows *n*, by fixing the pulley in *e* and *g* on the lines *a d*, *b c*. With 328 yards of cable, 20 to 22½ acres may be ploughed with this arrangement without moving the capstan.

Sometimes the capstan A (Fig. 52), is placed in the gravitation centre of the surface to be ploughed, and, without using any fixed pulley, the plough C works in the direction of the radii, as shown by the dotted lines ; but this arrangement, which does away with the fixed pulley and the waste of power incidental to it, necessitates the ploughing of convergent furrows, which are difficult of execution, and, if the workmen are not closely supervised, they leave portions of the ground unploughed. We visited a block ploughed by this system ; 7 per cent. of it had not been touched by the plough.

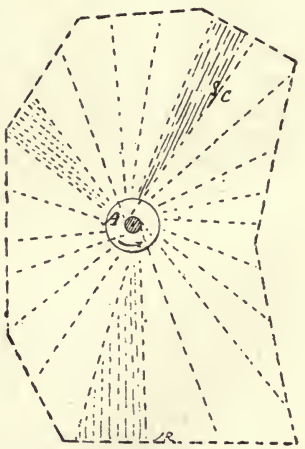
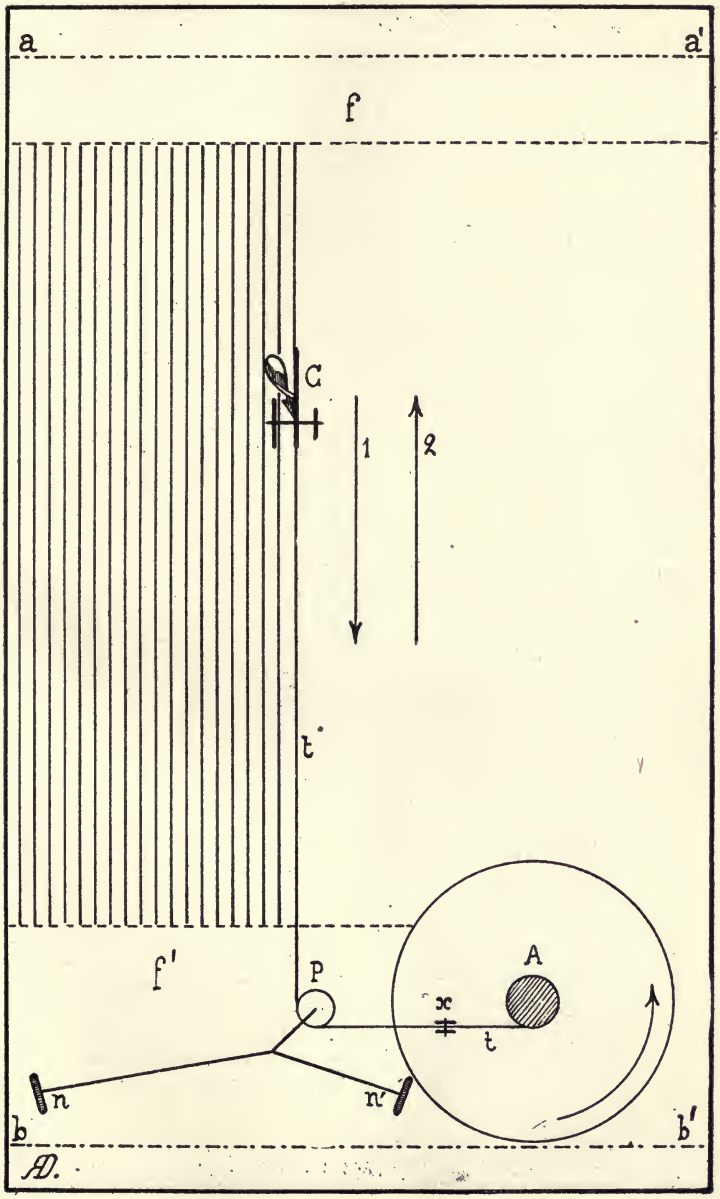


Fig. 52.

The installation of stationary capstans allows the use of a second cable, as shown in Plate VII. The drum A hauls the plough C, in the direction of arrow 1 by the cable *t* passing over the pulley P. The drum B revolving in an opposite direction, hauls the plough back by the cable *r* passing over the pulley *u*, in the direction of arrow 2. It is advisable to support the cable *r* on runners *m* moving sideways automatically with the cable.

Stationary capstans are built so as to be worked either by horses or steam power ; Pelous' drum (shown in Fig. 53) is an example of this principle.



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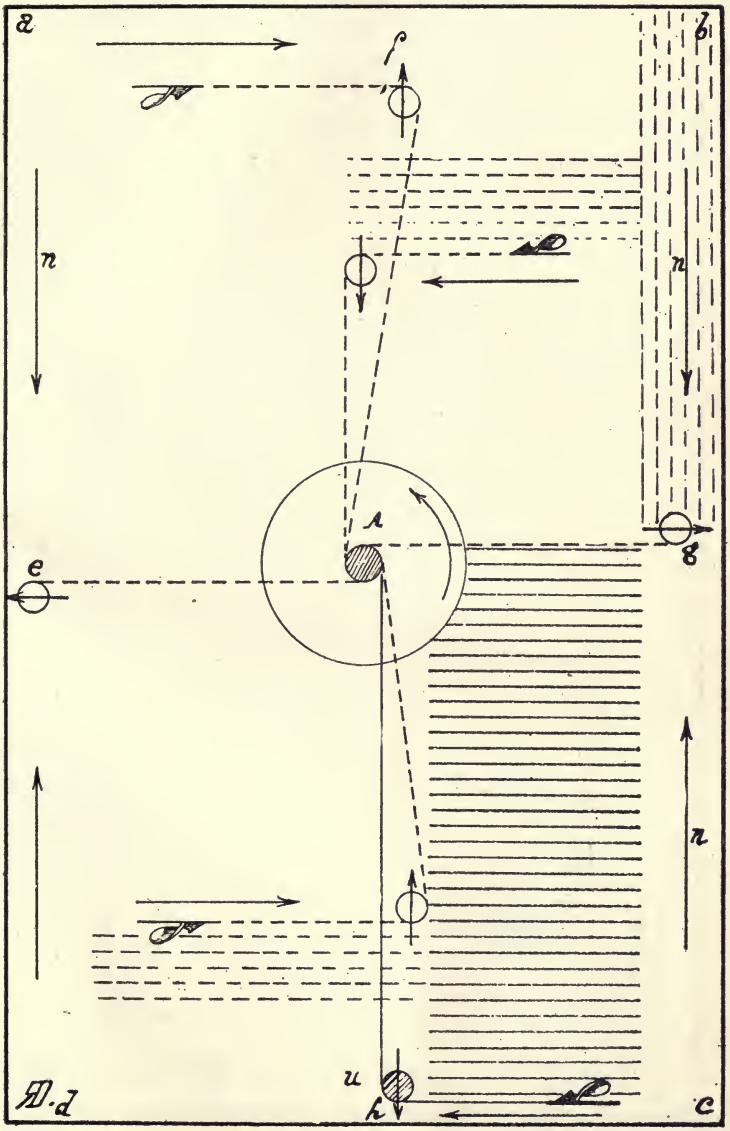
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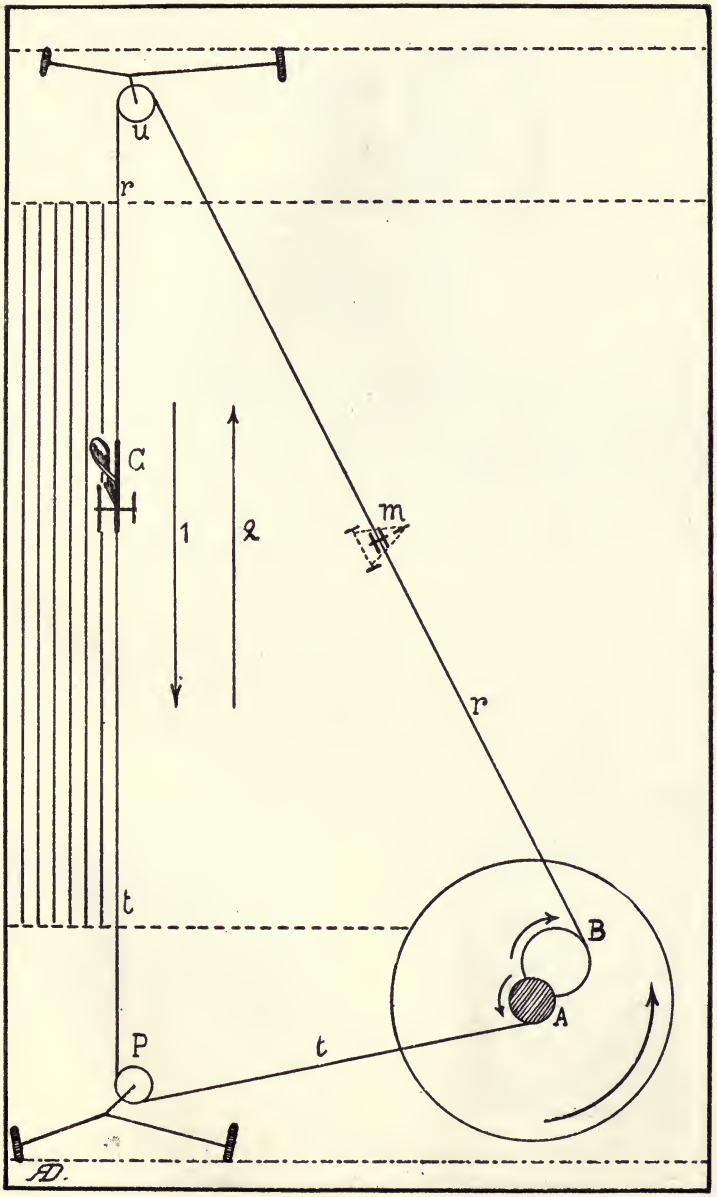
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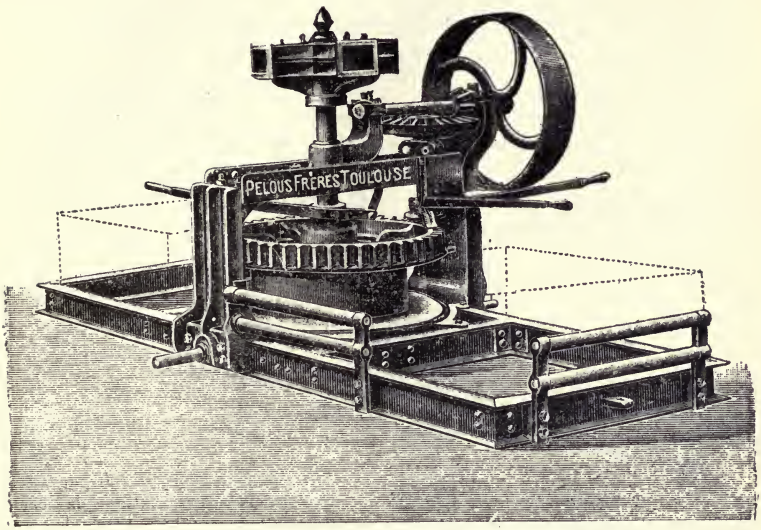

Fig. 53.—Pelous' Combined Capstan working by horse or steam power.

The fixed pulleys P (Fig. 54) are made of cast iron of a diameter varying between $23\frac{1}{2}$ and $31\frac{1}{2}$ inches, revolving around a steel pivot fixed in a block *a* secured to the anchor

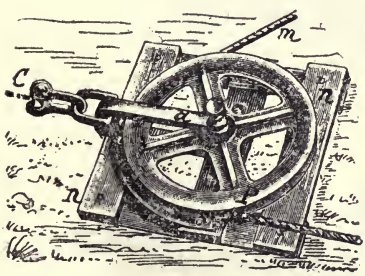

Fig. 54.—Fixed Pulley.

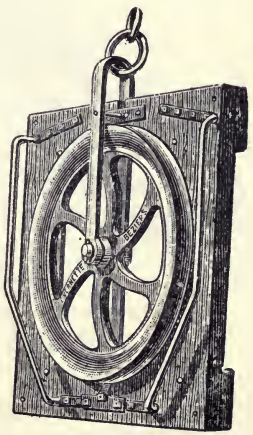

Fig. 55.—Pulley with cable-guard.

by means of a chain C. The whole arrangement is mounted on a wooden or iron square plate *n* of from $27\frac{1}{2}$ to $35\frac{1}{2}$ inches wide, on which is often fixed a triangular arrangement

called a cable-guard (Fig. 55), to prevent the cable from leaving the groove or getting jammed between the block and the sheave.

The block of the pulley P (Fig. 56) is fastened by a small chain *n* to the link of a large chain *a b c*, the extremities of which are secured to the anchors A A′; at each furrow the point of traction *n* is displaced in the direction of *b* a distance equal to the width of the furrow. If the traction cable C C′ is returned at a right angle on the pulley P, the effort *f* gives with effort *f′* * the resultant effort R which being reported on the point of traction *n*, may be resolved into its two components *p* and P, which represent the effort of traction exerted on the anchors A′ and A. This diagram shows that the anchor A has to support an effort much greater than the anchor A′ and also much greater than the effort *f* of the cable.

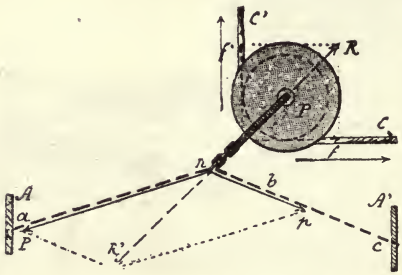

Fig. 56.—Diagram showing resultant of efforts of traction.

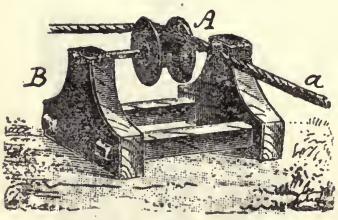

Fig. 57.—Stationary Runner.

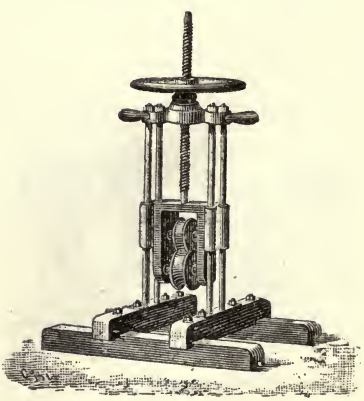

Fig. 58.—Stationary Runner used near the Capstan.

* The effort *f* is equal to effort *f′* (resistance of the plough and friction of the cable on ground), plus the friction resistance of the pulley and the resistance of the cable to bending round the pulley. Therefore, in reality, the effort *f* is a little greater than the effort *f′* and the resultant R is the diagonal of a rectangle.

For this reason great attention must be paid to the fixing of this anchor, as otherwise it would be pulled out during the course of work, involving undesirable waste of time. The chain *a b c* (Fig. 56) is about 65 feet long. After a certain number of furrows have been ploughed, this anchoring chain is displaced along the headland towards the capstan. The anchor A being fixed 65 feet to the right of the anchor A′.

Generally the cable is allowed to slide on the ground; however, when stationary capstans are used it is preferable to support the cable on runners. Figs. 57 and 58 represent stationary runners, the cable *a* passing in the groove of a pulley A revolving on a horizontal axle mounted on a wooden frame.

When hauling back cables are used it is advisable to support the small cable on runners travelling sideways automatically with the cable (Fig. 59). This figure shows one of these ; the pulley A is mounted on a wooden framework B travelling on three wheels R, revolving in a direction perpendicular to that of the cable. Movable runners are also made with iron frames (Fig. 60).

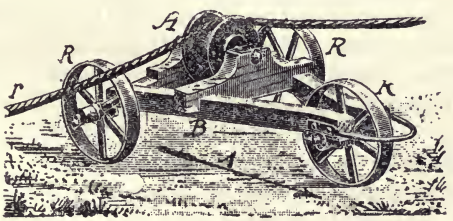

Fig. 59.—Movable Runner.

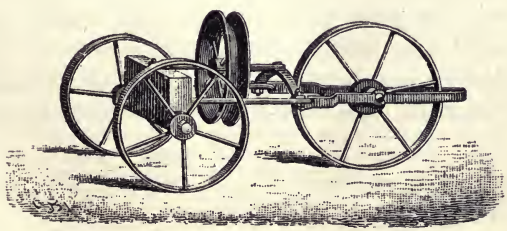

Fig. 60.—Movable Runner with iron frame.

Work of Horse Winding Drums.

The quantity of practical work done by a horse winding drum depends on the following conditions :—

Power of the team.
Resistance of the plough. (Nature of soil and dimensions of block.)
State of material.
Dimensions of block, and arrangement of plant.

The power of the team and the resistance offered by the soil are in relation to the section of the sod and the speed of the plough. That speed, together with the width of the sod and unavoidable losses of time, determine the amount of work done per hour.

The state of material bears by its mechanical yield on the traction power available on the plough.

The dimensions of the block, and arrangement of the plant, more or less favorable to the work, influence the time lost in proceeding from one furrow to another ; for instance, the longer the furrow the less the loss of time. However, other considerations may modify the arrangement of the plant, for instance, in very stiff soil it is advisable to run the furrows in such directions as to follow the fall of the ground to assist drainage of the water in the subsoil.

For light soils the season of ploughing has not a very great influence on the results of the operation. In clayey soils it is advisable not to plough when they are too wet, as the mould-board always exerts a certain compression on the sod, which makes it cling together like a brick, and forms large compact clods, often remaining in that state for many years.

The staff necessary for working the plant is generally increased by a few men, who remove large stones, roots, and bushes, which it is detrimental to leave in the ground.

The following is an example of the method of calculating the practical work of a trenching or subsoiling plant :—

	Yards.	Yards.	Yards.
Length of furrow ...	219	219	219
Speed of plough (inches per second)	2	2·75	3·94

Time required in Minutes:

To turn 1 furrow ...	67	48	34
Lost in various operations (lifting plough at end of furrow, 2 minutes; return 8 minutes; placing at start of furrow 5 minutes), total	15	15	15
Total required to open 1 furrow 219 yards in length	82	63	49

Practical Work per hour:

Length of furrow, in yards	158	207	262
Area ploughed in square yards, the width of the furrow being 25½ inches ...	112·8	149·4	187·2

The practical results shown by this last line would be modified if other lengths of furrows were considered, the time spent in lifting the plough out of the furrow and placing it in position at the starting point being independent of the length of furrow considered.

The depth of ploughing is generally fixed beforehand, and the width follows The section of the sod and the resistance of the soil per square inch give the mean hauling power required on the cable, from this the number of horses required to work the winding drum may be deduced, and from their energy the speed of the plough.*

We have already given several examples of the method of calculating the different elements of work for winding drums (traction of ploughs, power of teams, mechanical yields) we must now give some practical indications resulting

* If we designate by n the number of animals yoked to the drum ; t the mean power (in kilogrammetres, 7·233 foot-pounds, per second) which each horse may furnish (see page 65); m coefficient of reduction variable with the number of animals in the team (see page 66) ; k the mechanical yield of drum and cable varying between 0·8 and 0·9 ; p the depth of the furrow, varying between 14 inches and 27½ inches ; l the width of the furrow, equals $1·3 \times p$, varying between 15 inches and 35 inches; e the mean traction per square inch of section of sod, varying between 330 lbs. and 660 lbs.; v the speed of the plough per second in decimal fractions of a yard. The equilibrium of the system is given by the following formulæ :—

$$n\,t\,m\,K = p\,l\,e\,v,$$

or by

$$n\,t\,m\,K = 1·3\,p^2\,e\,v.$$

from ordinary field work. Dufaure has favoured us with details of his practical field work, from which we extract the following:—

With the object of planting a vineyard, Dufaure trenched land during 1889–90 to a depth of 16 inches, the nature of the subsoil not allowing it to be trenched deeper ; he used Beauquesne's plant, consisting of a fixed winding drum, a steel wire cable 274 yards in length, and a pulley hooked to the link of a chain anchored on the opposite headland by two anchors.

The winding drum worked by four horses could haul a very strong plough, but as the soil would not allow trenching to a very great depth, Dufaure, in order to make full use of the plant, fastened two ploughs to the cable, working to a depth of 15½ to 17½ inches, with a width of furrow of 19½ inches The extremity of the cable was made fast to a very strong swingle-bar 20 inches in length, one extremity of which was fastened direct on the whipple-tree of one of the ploughs, and to the other plough by a chain 10 feet in length.

When the two furrows were completed, the two ploughs were placed on their sledges and hauled back, this took from five to seven minutes, and was also indispensable to rest the horses working the drum.

The staff was—

3 men: 1 at the capstan, 2 accompanying the ploughs.

1 boy.

4 horses (in preference old buggy horses with long and steady stride).

2 bullocks, used to harrow behind the two ploughs, and to haul them back.

In a soil of medium stiffness the work per day of eight hours actual work, was 100 poles. It is to be noticed that except in the case of very bad weather, neither rain nor snow interrupted the work, as the horses had a hard tramped track to walk on.

The shifting of the winding drum was laborious, and required four skilful men working the whole day, to shift it from one block to another. It is advisable to reduce these shiftings by a little care in the choice of the different spots.

In a block of 17¼ acres the trenching took twenty days of actual work without shifting the drum, and, if Sundays and stoppages are taken into consideration, from the 23rd December to the 11th February. It was noticed that during this work the horses travelled at the speed most convenient to them, and without those jerks occurring so continuously when the horses are yoked direct to the trenching plough.

The cost of the whole material (drum, cable, pulley, ploughs) was £100.

The daily expenses were—

	s.	*d.*
4 horses at 4s.	16	0
2 bullocks at 1s. 7d.	3	2
3 men (per day 1s. 7d.; premium on work 4½d.)	5	11
1 boy	0	6
Writing off interest and keeping material in repair ...	3	0
Total	28	7

The cost of trenching 1 acre in 1⅛ day would be therefore £2 10s. This cost is a minimum, and it is better to allow between £3 8s. and £4 4s. for depths varying beween 15½ to 17 inches.

This is about the cost of the same work done by Verneuil, a neighbour of Dufaure's, who, not being able to utilize the winding drum on account of numerous banks of rock rendering the work too irregular, yoked five pairs of bullocks direct to a plough, similar to that used by Dufaure. But it must be noticed that during the month of January, which was very wet, Verneuil had to stop the work completely and feed bullocks which were not utilized, while Dufaure only lost five or six days in the same month.

Dufaure was able to plough a block 490 yards in length by lengthening the cable supported by a few runners; this great length of cable did not appear to increase the resistance much. The work of levelling was simplified by a wooden beam 4ft. 10in. in length, 6 inches in diameter, fastened at the rear and dragging on the soil, the soil being left much better levelled than when harrows were used.

Dufaure performed his ploughing from the 15th November to the end of February, and always noticed that horses which were very poor at the end of the summer, used to rest and fatten during the work of the winding drum, which works regularly without jerks on account of the elasticity of the cable, acting as a buffer.

De Juge * used for trenching his land, a winding drum hauling the plough direct and displaced at each furrow. From the 8th to the 20th December he ploughed 360 poles, of a soil formed of an agglomeration of clay and pebbles, to a depth of 24 inches. Taking into account the cost of bullocks and manual labour (which is very cheap in that district) the cost per acre reached £8.

At Fondouck (Algeria, 1898) a plant, comprising a Vernette winding drum stationed in the centre of the block, was worked by five mules, a man, and boy; the plough was worked by a man and boy, a team of two bullocks, and a horse and a driver to haul the plough back, that is to say (without counting the men digging out stones and large roots, staff paid for by the proprietor), altogether :—

3 men,
2 boys,
5 mules,
2 bullocks,
1 horse.

The depth ploughed was 14 inches, and 2½ acres were ploughed in seven days. The contractor did the work for the sum of £4 10s. per acre, the proprietor having to board men and animals. The plough turned a sod of 20 inches to 22 inches wide, and travelled at a speed of 4½ inches per second. The central position of the winding drum allowed, with a cable 328 yards long, and working convergingly, 21 to 35 acres to be ploughed.

When the soil is very stiff 28 to 32 poles only are ploughed per day.

In April, 1899, the swampy timbered land alongside the railway, between the Lincourt station and Bajac's implement yards, was trenched with a winding drum of the latter make (Bajac), yoked to two strong bullocks with single yokes, working at a depth of 18 inches, and a width of 20 inches, the plough travelled at an average rate of speed of

* Société des Agriculteurs de France, séance du 13 Fev. 1890.

3 inches per second. Lifting the plough at the end of the furrow and placing it on the sledge took from one and a half to two minutes. The winding drum also served to pull out stumps (2 feet to 2ft. 6in. in diameter) previously grubbed round to a depth of 2ft. 3in. and a width of 2 feet, after the fashion of a forest devil.

The cost of ploughing 1 acre with a horse-gin differs in each particular case. Here is, however, an example of the way of calculating it :—

A horse-gin, worked by four horses, taking, as an average, seven days to trench 2½ acres, the complete material costing £100, the annual writing off being 20 per cent. for a capital of £20.*

The daily expense of the work is :—

	s.	d.
4 horses at 4s.	16	0
2 bullocks at 1s. 7d.	3	2
2 men at 2s. 4d.	4	8
2 boys at 1s. 7d.	3	2
Total	27	0

That is to say, 27s. × 7 = £9 9s. per 2½ acres.

We may draw the following table by assuming a maximum of 200 days' work per year :—

Surface ploughed per year.	Number of days of work per year.	Cost per 2½ acres. Writing off Wear and Tear.	Work.	Totals.
Acres.	Days.	s. d.	s. d.	s. d.
12½	35	80 0		270 0
25	70	40 0	190 0	230 0
50	140	20 0		210 0
75	210	13 6		203 6

* The details of this capital are as follows :—

Writing off £100 in ten years at 4 per cent. ...	£8
Wear and tear at 12 per cent.	12
Total	£20

Representing in gross 20 per cent. of the capital (£100). In the above we do not take into consideration the interest of this capital, this latter being by a contractor pre-entered to his profit; that is to say, the difference between the price tendered and the cost of the work, *plus* general expense.

It will be interesting to compare these figures with those given later on for drums worked by steam power, to study the limits of economy of both systems.

The complete plant (drum, cable, pulley, plough) is worth from £80 to £100, which has to be written off in ten years. The steel traction cable costs from 4d. to 6d. per pound,* and weighs from 12 to 13 ounces per yard. A cable lasts from 150 to 200 days.

Under favorable conditions the cost of trenching or subsoiling 1 acre with horse-winding drums is under £6 8s.; if it exceeds this figure it is advisable to have recourse to other means for the execution of the work.

* These prices are subject to market fluctuations.

SPECIAL SUBSOILERS.

We will study in this chapter a certain number of special machines, which cannot be classed in the foregoing groups.

In 1857 Château, a solicitor at Fontaine-Guyon (Eure-et-Loir), constructed what he termed a *subsoiling car.** The machine resembled the frame of a dray, with two large wheels. The axle was fastened by two iron rods to a rectangular cast-iron block, provided with three stout teeth or tines 13¾ in. in length. At the end of each furrow the block, which weighed 176 lbs., could be lifted inside the frame by the aid of a rope and small windlass. In course of work, the vehicle was hauled by a team behind a plough, and, if necessary, the driver could sit upon the block and increase the weight, which would then reach 330 lbs., each tooth bearing a weight of 110 lbs. With a team of three horses the machine subsoiled to a depth of 15½ inches, "dragging out stones larger than a man's head."† In certain cases a disc for the distribution of fertilizers was fixed in front of the frame, the manure falling in front of the subsoiling teeth, which mixed it with the subsoil. In 1885, A. Derome applied the same idea to his manuring subsoiler. The Royal Society of Agriculture in England, awarded a first prize in 1850, at Exeter, in 1853 at Gloucester, and in 1854 at Lincoln, for a special machine constructed by Fowler, known as the steam mole-plough, the principle of which is similar to that of Reed-Slight's subsoiler. This mole-plough, which was exhibited and worked at the Agricultural Show at Moulins in 1869, is still in use in England, as shown in Fig. 61. It is constructed of a beam articulated in front, and provided at the rear with a handle; gearing wheels allow the beam to be raised at the end of each furrow. The working piece (Fig. 62) consists of a mole, kept at the required depth by a brace with cogs, held in position by a cotter; the inclination of the mole is given by another brace at the rear, bearing a thread and nut. A pivot is fixed in front of the beam, round which a loose pulley revolves, over which the traction cable passes hauled by a steam-winding drum. In stiff soils one of the extremities of the cable is fastened to one of the wheels of

* *Journal d'Agriculture Pratique*, 1859, vol. 2, p. 402.

† This depth of 15½ inches is evidently counted from the surface of the soil, including the depth of the preliminary ploughing. (Trans.)

the steam-engine (fixed point). The cable passes over the loose pulley of the mole-plough (Fig. 61) the other extremity winding on the drum. With such an arrangement the

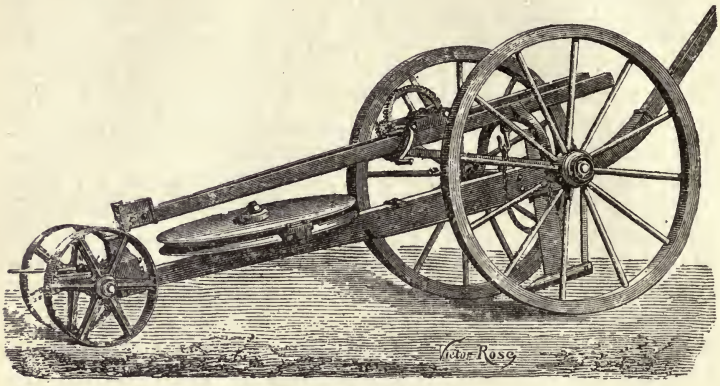

Fig. 61.—Fowler's Mole-plough.

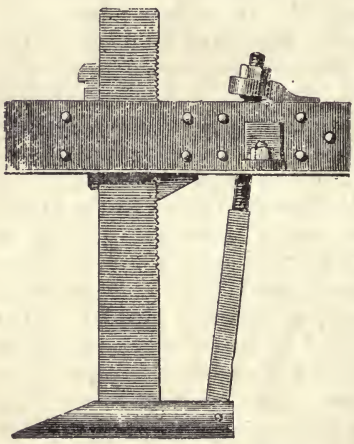

Fig. 62.—Mole of Fowler's plough.

traction on the plough is doubled, but the speed falls to half.

The work done by Fowler's machine depends on the shape given to the mole; that shown in Fig. 62 is used to make, by compression, underground drains at a depth varying from 27½ inches to 3ft. 3in. These drains last from fifteen to thirty years, and the cost is only 10s. per acre. But this kind of subsoiler can only be used in clayey soils free from stones. For ordinary subsoiling the mole may be replaced by subsoiling teeth.

Ransomes used to make a special subsoiling machine called Beauclerc's *Archimedian subsoiler;* this machine resembled that of Reed-Slight, but at the rear of the share an Archimedian endless screw was fixed revolving round an axle. According to the inventor, the strip of soil cut by the share would revolve this screw, and thus stir the subsoil, lifting it to a certain height to let it fall crumbled

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behind the plough. We have not been able to find any documents on the practical work of this machine, but it is almost certain that the soil jamming in the axle would prevent the rotation of the screw. This, however, happened with similar machines exhibited since Ransomes', although great care had been taken to protect the bearings against the introduction of any particles of soil.

Subsoiling machines have been constructed on another principle, the working piece revolving in the vertical plane, the subsoiling teeth being fixed to the tire of a wheel ; such is the principal adopted by Guibal, of Castres (Tarn). We quote Londet's remarks, who witnessed many trials of this machine :—*

"Guibal's subsoiler appeared for the first time at the agricultural show held at Versailles in 1851. Subsequently the inventor added many improvements (Figs. 63 and 64). These figures show the machine as it appeared at the Universal Exhibition at Paris in 1855.

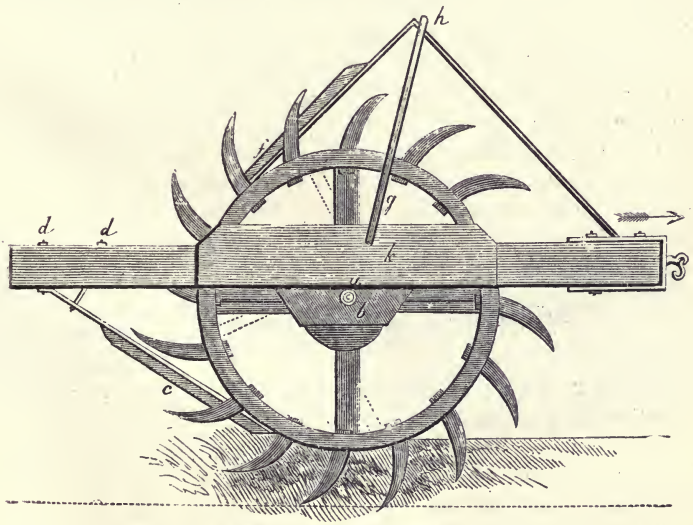


Fig. 63. - Guibal's Subsoiler.

"Guibal's subsoiler (Fig. 63) consists of a cast-iron wheel 31½ inches in diameter, provided with sixteen pairs of curved teeth, or tines, 12 inches in length.

* L. A. Londet, professor at the School of Agriculture, Grand-Jouan, *Instruments Agricoles, machines et outils* (Exhibition of 1855).

" Guibal found from experiments that the weight of the machine should be 1,056 lbs. to enable the teeth to penetrate throughout their length in soils of medium stiffness ; he advises weighting by cast-iron blocks, fixed between the spokes by means of bolts, or to fix on the frame *k*, wooden cases, which may be loaded with earth (Fig. 64). The first of these two

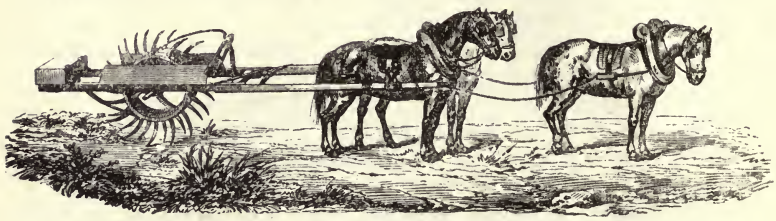


Fig. 64.—Guibal's Subsoiler at work.

means of increasing the weight should be preferred, for the weight acts more directly on each tooth. The wheel revolves round an axle *a* fixed on the wooden frame *k* made as narrow as possible. On the rear of the frame a paddle board *c* is fixed, so as to engage between each pair of teeth, forcing the soil to fall back in the furrow directly it is raised.

" Another paddle board *f* is fixed to the front of the frame, and, engaging between the teeth, forces the soil to fall over two iron plates fixed slantingly on each side of the frame. By this means the soil is deposited on one side of the part already ploughed, on the other on the part which is to be ploughed; as a result the subsoil is disposed between two layers of arable soil. According to the nature of the soil, either of the paddle boards is used.

" A lever fixed on the axle enables the machine to be kept in equilibrium (Fig 65).

" One or two poles for the yoking of horses or bullocks completes the machine.

" In course of work the wheel revolves, the teeth penetrating the soil ; the work cannot be better compared than with that of a hand hoe.

" As in the case of any other subsoiler, Guibal's machine works in a furrow previously opened by an ordinary plough. Two men and four horses are generally required. We see from this that its work costs double that of the plough. Stones, roots of trees, &c., do not handicap the work of this subsoiler.

"We have used, and also seen, Guibal's subsoiler, in use; compared against others, such as Smith's or Reed's machines, the work of the former has always been more satisfactory.

"For travelling this machine on roads ordinary wheels are fixed to the axle *a* preventing the teeth from touching the ground. We cannot end this chapter without stating that, in our opinion, it is one of the best machines, and destined to render great service in intense culture." *

Guibal's machine was very unstable; it had a tendency to tilt sideways, and had to be kept vertical by a man acting on a lever prolonging the axle. Rolland, professor at Grand-Jouan, thought of fixing two wheels to the frame, and had a machine made to his own designs for Baron Thenard, who called the machine "*digger*," and improved it in several details, notably in mounting the wheels on a bent axle, which could be raised by means of a lever. A description of it is given in the *Journal d'Agriculture Pratique*, 1858, vol. 1, p. 220.

Thenard's digger (Figs. 65 and 66) consists of two large parallel wheels 6ft. 6in. in diameter, 4 inches apart, and running loose on the axle; the spokes are made of wood, and the iron tires provided with curved tines 11 inches in length. Each wheel weighs 660 lbs. The frame is provided with a paddle-board as in Guibal's machine.

Fig. 65. - Thenard's Digger at work.

The axle, 2 inches in diameter, has two bends at right angles 11½ inches in length, and is terminated by two axle arms, upon which ordinary wheels revolve, for moving the machine about. The whole appliance is fixed

* Guibal applied the same principle to the construction of hoeing rollers, used for surface work (length, 3ft. 11in.; diameter, 21½ inches; length of teeth, 5 inches).

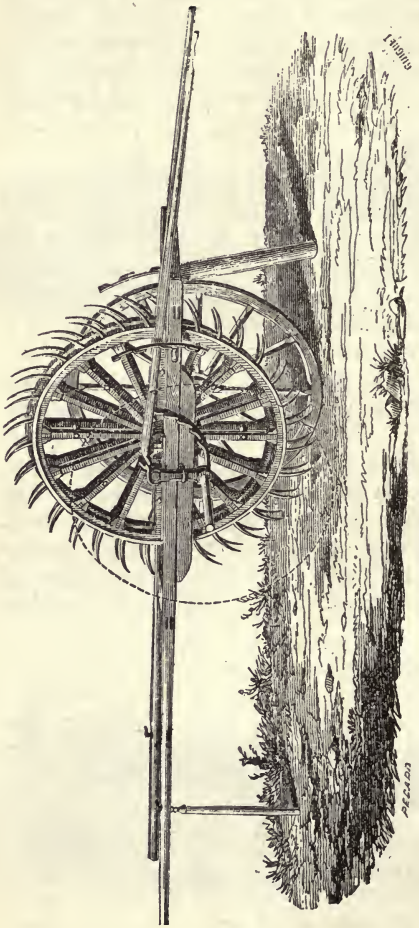


Fig. 66. - Thenard's Digger.

on a kind of dray-frame (Fig. 66). The position of the subsoiling discs with regard to the wheels, which are always in contact with the soil, is regulated by means of a bent axle. The discs are lowered or raised by means of two levers (one on each side) 13 feet in length, which can be clamped on a ratchet sector.

These levers might be replaced with advantage, by any device actually in use. The depth of subsoiling may be modified, or the disc lifted out of the ground altogether, so as to turn at the end of a furrow or for being moved about. If only one man is to lift the discs, he has to act upon each lever in turn. In the experiments one man took one and a half minutes to lift the discs, while two, acting simultaneously, only took half a minute.

With a plough working to a depth of $12\frac{1}{2}$ inches followed by Thenard's digger (11 inches), the depth of cultivation reached $23\frac{1}{2}$ inches.

At Baron Thenard's property, in fairly compact soil, three good horses were required to pull a plough working to a depth of 7 inches, the subsoil being very hard on account of the prolonged drought of 1858. The digger required four good horses to disturb the soil 11 inches deeper, but it was

found advisable to use five, the depth of cultivation reaching 18 inches. If we consider the above figures we are in a position to see that if we represent by ten the resistance of the unity section of the arable soil opposed to the plough, that the resistance opposed by the subsoil to the digger is eleven.

In the short days of November, doing only six hours of actual work, the area worked per day was from 136 to 144 poles. The whole plant required is the ordinary plough and team, plus five horses, a driver and two men for the digger.

Let us study the work of one tine of Guibal's machine. If the disc A (Fig. 67), has a weight P, sufficient to pre-

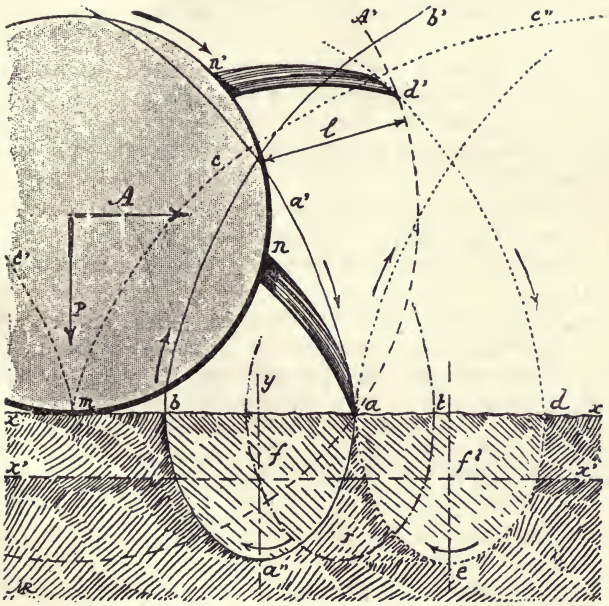


Fig. 67.—Diagram showing the work of a Subsoiler.

vent it from sliding, any point of the circumference m describes in the vertical plane a series of curves $c' m\ c\ c''$ called cycloids. If the point a is outside the circle, the trajectory described by that point is a curtate cycloid.*

* We may mention that cycloids (common cycloid, curtate cycloid, and prolate cycloid) are curves generated by a point in the plane of a circle, when the circle is rolled along a straight line, keeping always in the same plane, and possess the following properties:—In any point of the curve, the normal to that curve passes by the point of contact of the circle A with the fixed line x. For instance, for the portion $a\ a''\ b$, which interests us, the normals in a and b coincide with the plane x of the soil. In a'' the normal y is perpendicular to $x\ x$.

The point of a tine $a\ n$ describes in the soil a trajectory $a\ a''\ b$ disturbing a volume of soil represented in section by f. Practically the section worked is a little larger on account of the tearing taking place in the part $a''\ b$.

We see in diagram 67 that the profile $a\ n$ of a tine must be inside the cycloid $a\ a'$ generated by the point a. If this condition is not fulfilled, the back of the tine compresses the soil in the part $a\ a''$. This waste of power has also the disadvantage of forcing the wheel to slide on the ground.

To obtain satisfactory subsoiling it would be sufficient, after the tine $n\ a$ has disturbed the part f, for the next tine $n'\ d'$ to disturb the part $d\ e\ a$, for the zone r is torn away.

From the above it results that the distance apart $n\ n'$ of the teeth on the circumference of the disc a, must be at the maximum equal to $b\ a$ or $a\ d$. By setting the tines closer together the section r, which has to be disturbed by tearing, is diminished.

In Guibal's subsoiler the radius of the disc A was 15·7 inches, the length l of the teeth was 12 inches, the distance apart $a\ d'$ of the points was 11 inches, that is to say, the distance $a\ d'$ was $\frac{9}{10}$ of the length l of the teeth. If we draw the diagram relative to the work of Guibal's machine, we see that the teeth successively describe curtate cycloids, having within the zone of work the following dimensions:—

Chord $a\ b$	15 inches.
Arrow $y\ a''$	12 inches.
Distance apart of two successive trajectories $a\ t$	6 inches.

Under these conditions the whole depth $y\ a''$ of soil could be thoroughly disturbed.

When the weight P of the disc is not sufficient to overcome the resistance to penetration of the subsoil, a portion only of the teeth penetrates, the periphery of the disc A not being in contact with the soil. Under these unfavorable conditions the surface of the soil (Fig. 67) must be considered as being $x'\ x'$, and the zone of action of each tine diminishing in depth as well as in width, may leave, in certain cases, portions of the soil untouched.

It appears that machines built on this principle were discarded after 1860. It would be interesting to ascertain if their principle was wrong, or if the construction was defective at that period. Unfortunately we have been unable to find any literature answering this question.

We have seen that Guibal, in 1855, had applied this principle to his hoeing rollers. Since then different models have been constructed for surface ploughing. In this type of machine we may mention that of A. de Souza (1891) Morgan's pulverizer, and the mechanical hoeing machines exhibited by Messrs. Ch. Galland, Grandjon, and Co., at the Agricultural Show held at Paris in 1894.

Galland and Grandjon's digger consists of a small Guibal roller, in which each pair of steel tines is fixed in a cast-iron disc keyed on a horizontal axle, in the centre of which is a gearing wheel. On the right and left of this wheel are discs, provided with tines, and varying in number according to the width to be worked. At a distance of 31½ inches above the level of the soil, is a horizontal axle, which a man revolves by means of two handles; this axle, by means of cog-wheels and chains, revolves the axle of the digger supported at the rear by two wheels acting as a regulator for depth. The width worked is 18 inches, the depth 4 inches. Certain models proposed for hoeing plants in a line, such as vines, are mounted on a light frame carried by four wheels. The depth worked in this case is 6 inches, and the width 21½ inches.

Recently, in Italy, the agriculturist, Luigi Pavese, proposed a hoeing machine* which may be considered as three Guibal subsoilers, between which shovels worked by a certain movement of rotation pass. We have no precise information as to the work of this machine.

We may state, in conclusion, that the principle of Guibal's subsoiler is applied to the machine of Paul, of Norfolk (1854), used to open trenches 4ft. 10in. in depth. This machine, which is worked by a horse-gin and chains, is not within the scope of this article.

* *La macchina Vangatrice Automatica dell' agronomo Luigi Pavese, l'Economia Rurale,* Torino, 24th November, 1899.

COMBINED PORTABLE ENGINE AND WINDING DRUM.

Displacement System.

For the trenching or subsoiling of small areas horse-gins are very cheap when the work can be done by the horses already on the place, but when the surface or area annually ploughed is over 37½ acres, it is advisable to work the winding drum by a steam-engine, especially if the latter is already on the property. Contractors for thrashing or chaff-cutting may in the same way use their engine to do trenching or subsoiling by contract. The first systems originated from Howard's machine, used formerly for ordinary shallow ploughing; subsequently constructors aimed at making machines which could be easily displaced at each furrow.

As a rule, the intermediate shaft of the winding drum is revolved by a belt or chain connected with the pulley of the engine; a gearing system being interposed between the shaft and the drum. A special device is attached for throwing in or out of gear without stopping the engine. There are often different arrangements of cog-wheels keyed on the intermediate shaft of the winding drum, allowing two or three rates of speed to be obtained. The length of the cable varies between 274 and 328 yards.

When the plough is to be hauled back by the engine, a second winding drum is attached to the system, revolving at a speed three or four times greater, the length of the hauling-back cable being 547 yards.

These different systems of winding drums are made so as to be connected to any kind of engine, which presents some difficulty in the case of direct traction. We will quote some examples later on. For a direct traction arrangement, the portable engine must be connected to the winding drum so as to form a rigid system, the whole being displaced at each furrow, while, in the stationary arrangement the portable engine is fixed at a certain distance from the winding drum, as in the case of a chaff-cutter or thresher. The stationary steam plants require fixed pulleys, as in the case of stationary gins.

The displacement of direct traction steam combinations along the headland is done by means of levers or small hauling

cables, 98 feet in length, fixed to an anchor. A man passes the small cable over a pulley fixed on the frame, and pulling backwards readily displaces the system, as it travels easily on rollers and rolled joist iron girders. These girders must be sunk in the ground. If it is too hard, they require to be steadied by means of pegs.

The drums must always be provided with brakes (automatic or otherwise) to steady the unwinding of the cable; if not, the latter, unwinding by jerks, becomes entangled in the different parts of the machine, and occasions great loss of time. The most simple automatic brakes consist of a weight, which may be displaced along a lever, at the end of which a shoe is fixed, compressing against the flange of the drum.

Stationary winding drums are generally made with a vertical shaft, so as to allow the cable to unwind in different directions, without requiring an arrangement of pulleys, but this requires the use of bevel pinions to transmit the movement from the engine to the drum. In the direct traction system the drum generally revolves round a horizontal shaft, the cable winding with or without the aid of a pulley arrangement, according to the direction of the traction.

Finally, for travelling on roads, the drums are usually mounted on four wheels.

Guyot's winding drum (Fig. 26, page 51) consists of a large rectangular frame, made of rolled joist iron girders, upon which the portable engine is carried; the fly-wheel of the latter is connected by means of a belt to the pulley of the capstan, which is fixed at the other extremity of the frame. A pinion is keyed on the shaft of the pulley, gearing with a cog-wheel keyed on another shaft, together with another pinion, gearing with the large crown-wheel of the drum upon which the cable winds direct.

The large frame is carried by four rollers, travelling on rolled joist girders. The displacement of the system is easily managed by means of levers*; the latter may be inclined at an angle to allow the system to turn about if the headland is not straight, or at the end of the headland, in order to plough it.

* Guyot tried to displace the system automatically by means of a belt, pulleys, and gearing system, revolving the axle of the rollers when required. This complicated mechanism (1891) has been discarded.

To haul the engine on the frame, a wooden inclined plane is placed at the end; the drum worked by hand serves to haul the engine into position.

The work of one of these winding drums on the property of L. Perrière, at Salauze (Aude) was followed by P. Castel, engineer, who published an account in the Bulletin of the *Société centrale d'agriculture de l'Aude*. From his account we condense the following :—

The drum was worked with a 7 H.P. engine, consuming 343·2 lbs. of coal in ten hours, costing 21s. 2d. per ton ; in a day of ten hours the engine required 220 gallons of water.*

The drum was 19·7 inches in diameter, 35·4 inches in width; the cable 0·63 inches in diameter, 274 yards in length. The plough was hauled up a hill in compact soil, composed of pebbles and clay ; the bottom of the block was sandy and light. The furrow was 24 inches deep and 27½ inches in width. At the bottom of the block the depth was 27½ inches. The average speed of the plough was 12 inches per second.†

The furrow was 265 yards in length ; on the engine side the headland was 20 feet in width ; on the opposite, 11 feet.

At the end of each furrow two men lifted the plough, ready to be hauled back, this operation taking one minute ; a pair of bullocks took the plough back to the bottom of the block, where one man was sufficient to put it into position. Two men attended the engine and drum, displacing it while the plough was being hauled back.

The time required to open a furrow was :

Work of the plough	11·5	minutes.
Lifting the plough for hauling back	1·0	„
Hauling back	2·5	„
Placing in position	0·5	„
Total ...	15·5	„

According to this, 232 poles may be ploughed per day of ten hours.

At Salauze 34 furrows only were actually ploughed, equivalent to 208 poles.

* These figures for 7 H.P. give per H.P. per hour 48·4 lbs. of coal, 3·74 gallons of water ; 2·2 lbs. of coal therefore vaporizes about 1·76 gallons of water.

† The weight of the system, which is 7,400 kilos (7 tons 5 cwt.) (frame and drum 3,000 kilos, portable engine 3,800 kilos, water in the boiler 600 kilos) is sufficient to prevent it from sliding under the action of the traction.

P. Castel estimates the expense of the material and the expense of working this arrangement at—

Cost of material—

7 H.P. portable engine	£232
Frame, capstan, accessories	120
Cable	10
Plough	28
Total	£390

In round numbers, £400, which he estimates must be written off in five years, that is to say, £80 divided over 200 days work per annum, that is to say, 8s. per day of work.

The interest on the capital at 5 per cent. represents 2s. per day, which increases the fixed cost per day to 10s.

The daily expense is—

Fixed cost			£0	10 0
Engine-driver, boarded ...	£0	4	9	
Workman	0	2	4½	
Ploughman	0	2	4½	
Pair of bullocks and driver ...	0	4	9	
343 lbs. of coal at £1 1s. 2d. per ton	0	3	6	
Lubricating oil	0	0	5	
			0	18 2
Total ...			£1	8 2

If the plough works 160 poles per day the cost of ploughing 1 acre to a depth of 24 inches is £1 8s. 2d., out of which 18s. 2d. represent labour.*

The pair of bullocks may be dispensed with by hauling the plough back with a small cable passing over a fixed pulley anchored on the opposite headland, winding round a small drum keyed on one of the intermediate shafts.

In systems such as that above described, the action of the drum being perpendicular to the direction of the furrow, the cable does not need to pass over a pulley arrangement. With the object of diminishing the width of the headland the axle of the drum is sometimes placed parallel to the direction of the furrow; in this case the cable passes over a pulley arrangement.

* In this estimate the keeping in repair, carriage of water and coal, is not mentioned.

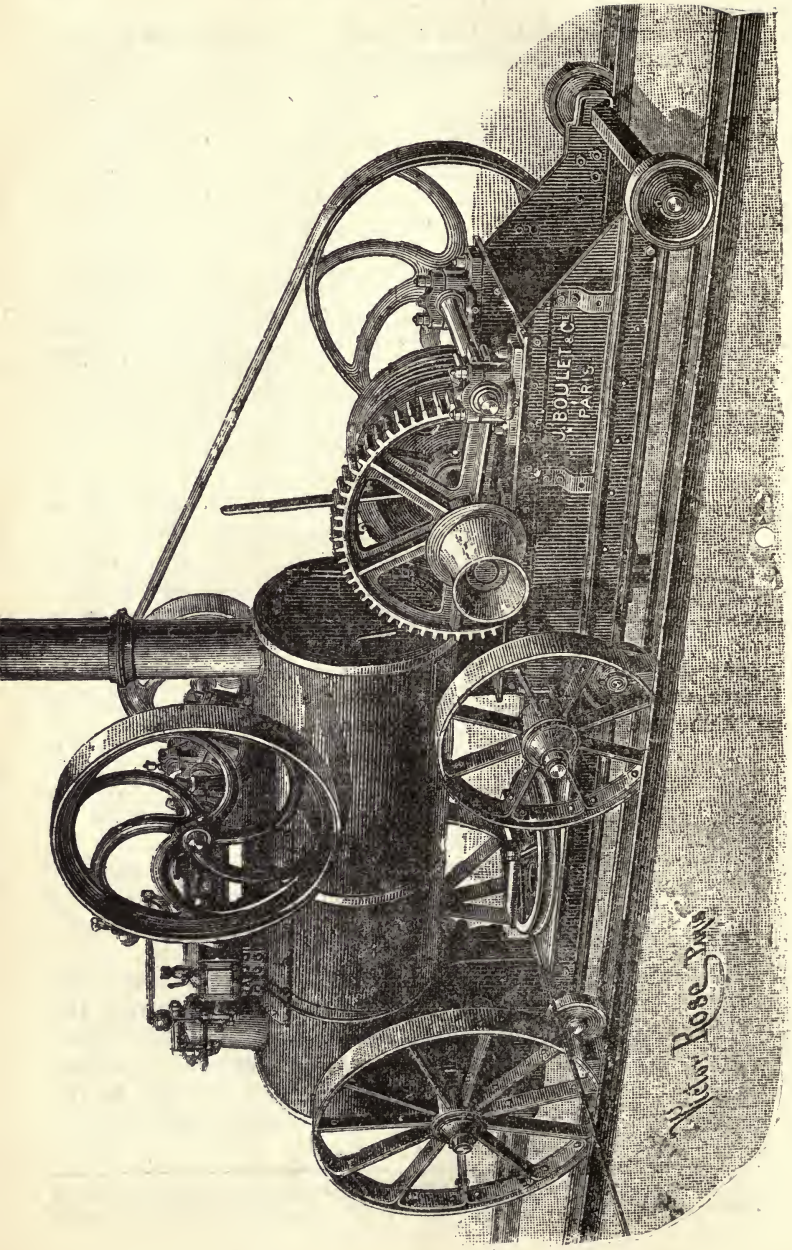


Fig. 68.—Steam Winding Drum of Boulet, Brûlé, and Co.

Such an arrangement is shown in Plate VIII.

This winding drum was exhibited by Boulet, Brûlé, and Co., at the Agricultural Show held at Paris in 1892. It may be attached by means of iron straps in front of any portable engine ; the cable passes over a horizontal pulley fixed upon the frame of the drum under the engine. The whole system travels on rails, the displacement being effected by a small capstan fixed in front of the frame of the drum, operating on a rope anchored in the line of advance. Fig. 68 represents a machine with a single drum, the plough being hauled back by a team. In certain cases, as we shall hereafter see, two drums may be used, one of these serving to haul the plough back, opening a furrow at the same time if a balance-plough is being used.

Systems in which the plough is hauled back with a smaller cable are numerous. We will only mention two examples. To keep the two cables apart a fixed pulley B (Plate VIII.) is anchored at some distance in the field. The drum A winds the traction cable *t*, passing over the pulley *a* and fastened to the plough C ; the return cable winds over the drum R, after passing over the pulleys B and *b*. The engine M and the pulley *n* are displaced after each furrow in the direction of arrows 1 and 2, the pulley B remaining stationary while a certain number of furrows are turned.

Fig. 69 represents Pelous' system ; on the frame A, mounted on four rollers *g*, the portable engine M is placed ; a toothed-wheel, gearing with a chain *m*, is keyed on the main shaft of the latter. The intermediate shaft of the winding drum gears directly with the drums L and R, on

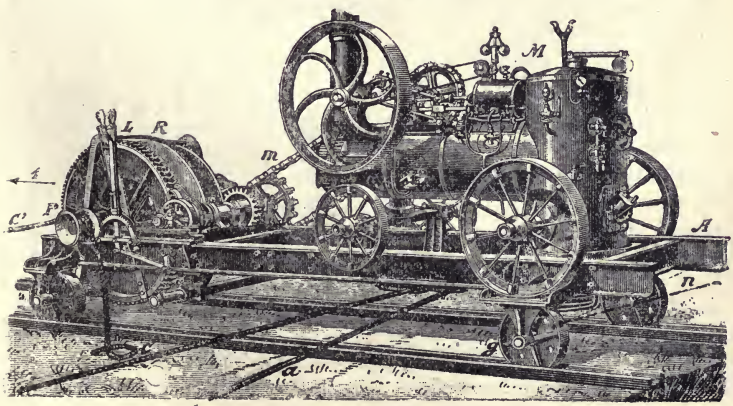


Fig. 69.—Pelous' Steam Winding Drum.

which the cables wind, after passing over the horizontal pulleys keyed under the frame A (in the Figure, *a* is the traction, and *x* the return cable). The displacement of the machine in the direction of arrow 1 is effected by the cable C C′, which is coiled two or three times round the surging drum, and held taut by the engine-driver; the other extremity of the cable being anchored at a certain distance, the whole system may be moved towards it. The displacement may also be effected by means of levers *n* inserted in holes in the rim of the rollers.

In the Hidien system (patented November, 1897) instead of mounting the engine on the frame of the winding drum, the latter H (Figs. 70 and 71) is put in the place of the

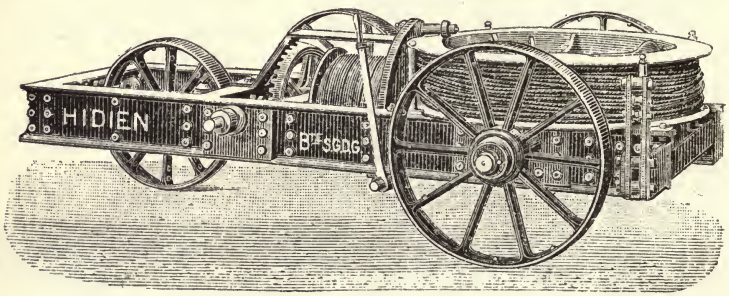


Fig. 70.—Hidien's Winding Drum.

forecarriage of the engine M, the motive power being transmitted by the belting *n* to the intermediate shaft, upon which a double bevel-wheel and pinion are fixed, the large wheel of which revolves at the same time both the traction drum A and the return drum R, the large drum revolving round a vertical spindle to facilitate winding; the whole system travels on rolled joist girders.

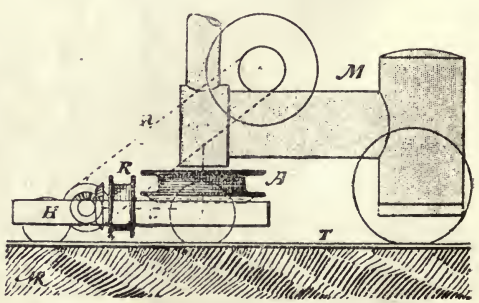
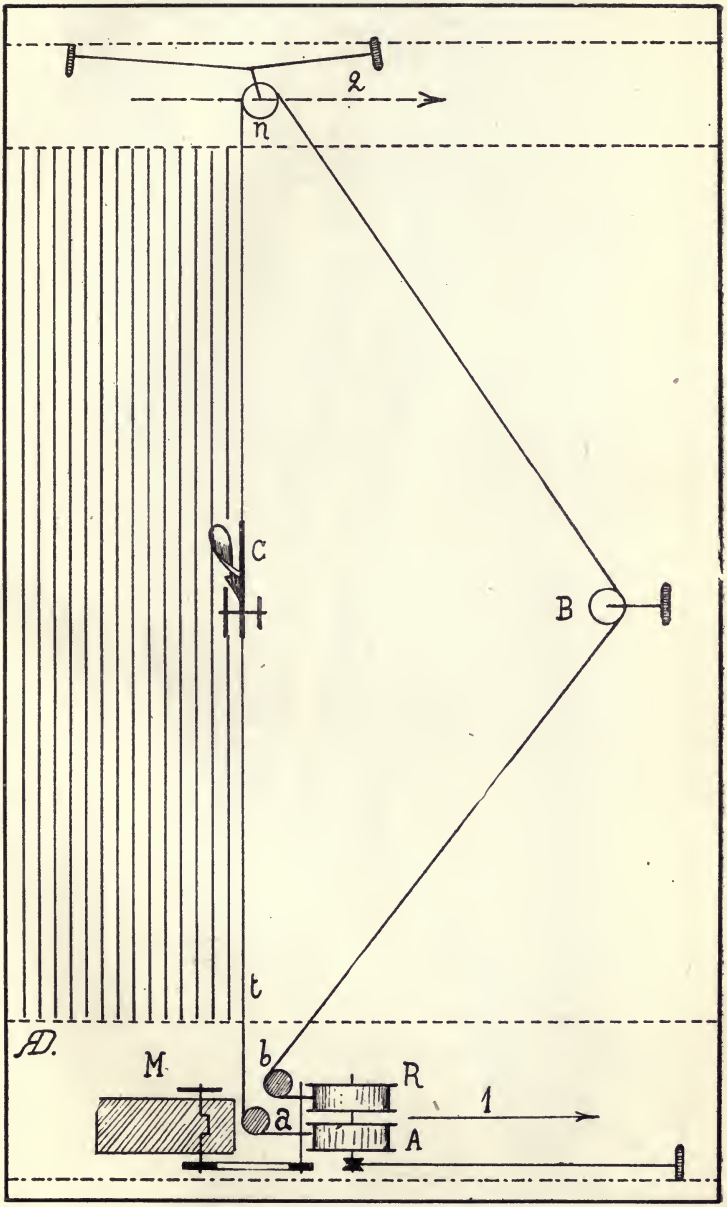


Fig. 71.—Diagram of Hidien's Steam Winding Drum.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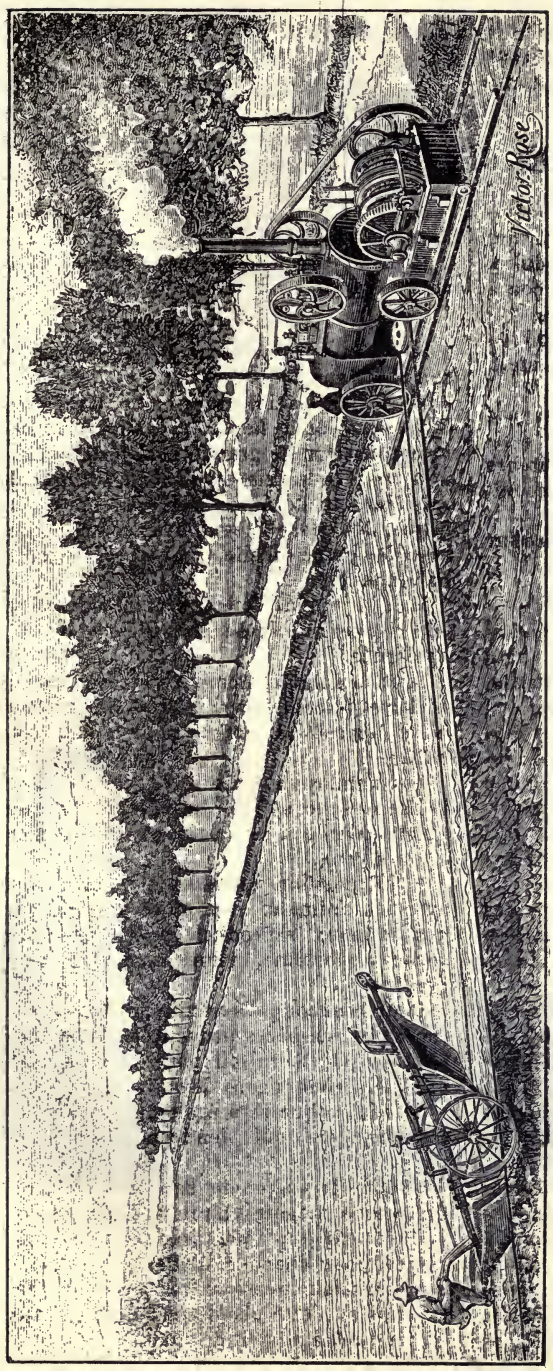


Fig. 72.—System with two Traction Drums at work.

Systems with two traction drums, drawing a balance-plough backwards and forwards, are in use. One of the cables passes over a pulley fixed on the opposite headland. Fig. 72 represents one of these at work. In this system the two winding drums are of equal diameter, but that winding the return cable is wider as it has to accommodate double the length of cable.

Combined Portable Engine and Winding Drum.

Stationary System.

When the system is fixed stationary in a given position in the field, the old Howard system (shown in Figs. 73 and 74) may be adopted. The two drums run loose on a shaft fixed on an eccentric; a lever allows the cog-wheel of each drum to be raised and thrown into gear with the pinions keyed on the intermediate shaft, carrying the belt pulley. When the drum is thrown out of gear, its flange rests on the shoe of the brake, which is kept in position by a counterpoise (not shown in this figure). The frame of the drum is carried by two wheels. The shafts of the frame are attached to the rear of the engine, the cables passing under the platform where the engine-driver stands, then over the two pulleys fixed on a special frame bolted on the forecarriage of the machine. Plate IX. shows the working installation.

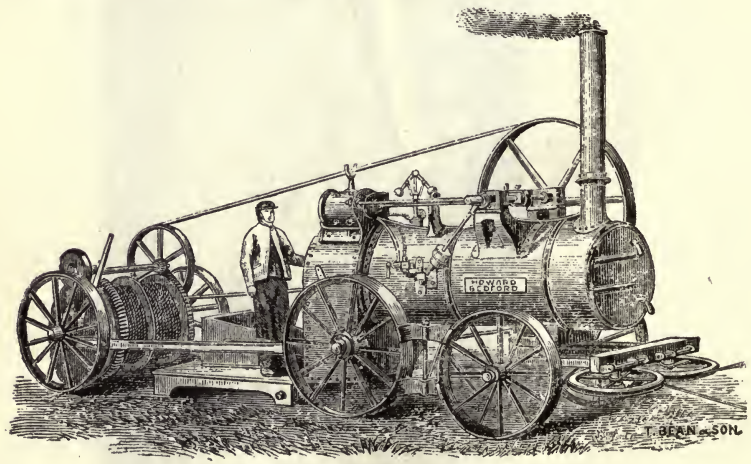
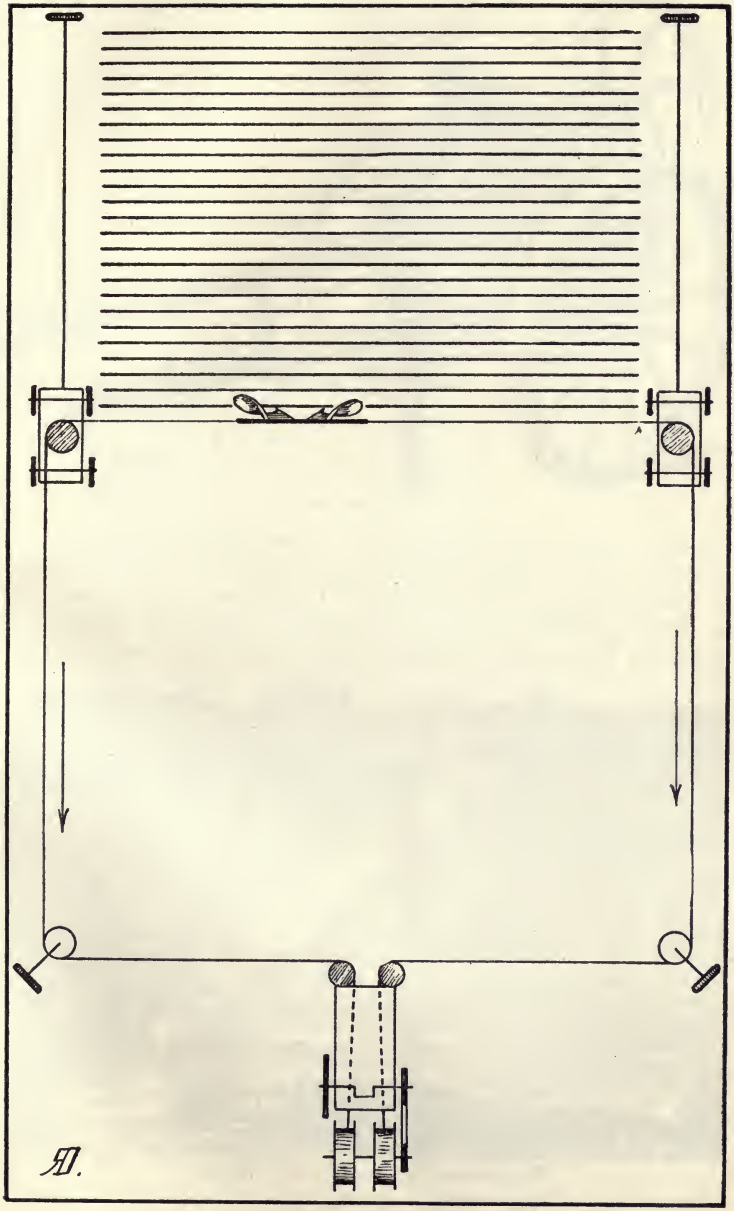


Fig. 73.—Howard's Winding Drum worked by a portable engine.



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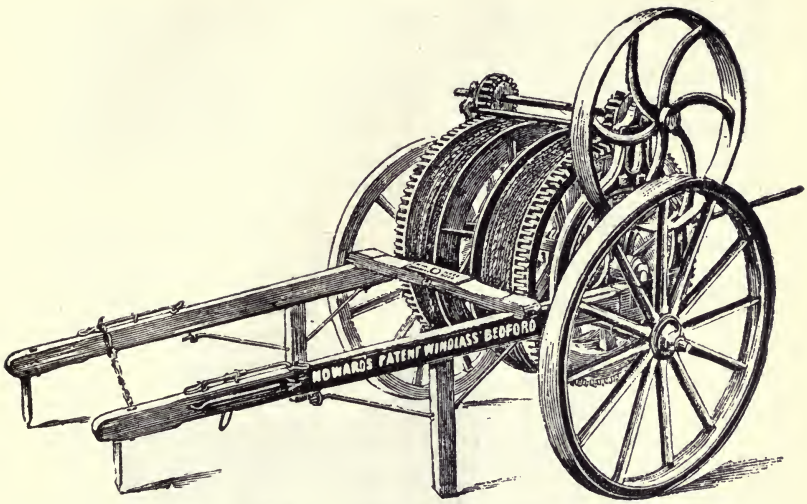


Fig. 74.—Howard's Winding Drum.

The same system, only with a single drum, was used by Gustave Scribe in 1877 to subsoil, to a depth of 24 inches, 75 acres of land near Gand.* Fig. 75 shows a general view of the plant, consisting of a portable engine, a winding drum, a pulley fixed on a long wooden frame, on the end of which is

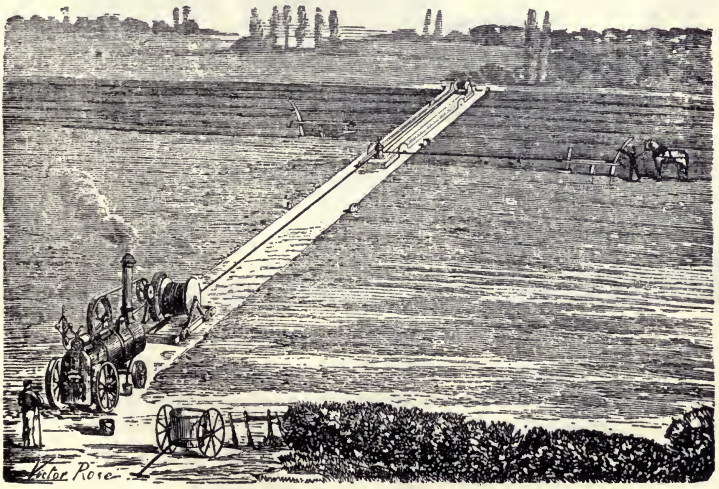


Fig. 75.—G. Scribe's Arrangement in the field.

* *Journal d'Agriculture Pratique*, 1897, vol. 1, p. 829.

a small windlass, which, by unwinding, allows the pulley to be drawn towards the engine. The subsoiler only worked in one direction, a horse drawing it back with a cable 274 yards long. Seven and one-half acres could be ploughed without shifting the engine. Gustave Scribe wished to apply this system to the polders of Zealand, where stiff soils 4 feet in depth are only ploughed to a depth of 9½ inches.

The winding drums in actual use (Vernette, Guyot, Amouroux) generally rotate vertically, when the plough is to be hauled back by a horse. Figs. 76 and 77 represent Vernette's winding drum mounted on wheels for travelling on

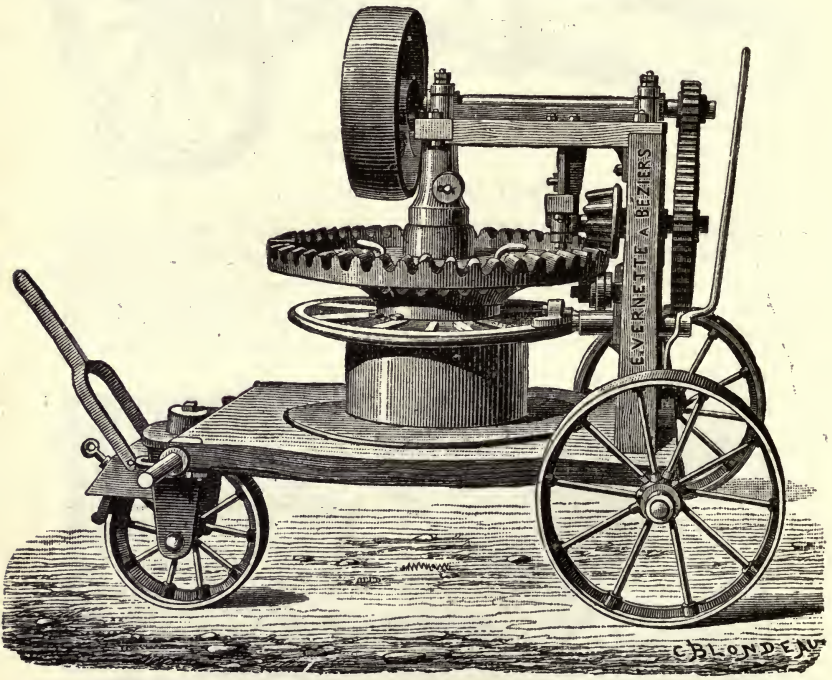


Fig. 76.—Vernette's Winding Drum.

roads. In work, the wheels are removed, and the machine fixed on the ground. A belt connects the pulley of the engine to that of the winding drum. Different gearing systems may be interposed between the pulley and the drum to modify the speed.*

* In the old model, the transmission of the shaft of the pulley to that of the drum was made by means of a spiral gearing. This system was applied by Grué in 1891.

In the old Beauquesne winding drum there were two cog-wheels and two pinions, which varied the speed according to their position.

We have already described Pelous' convertible horse or steam-power winding drum (Fig. 53, p. 87).

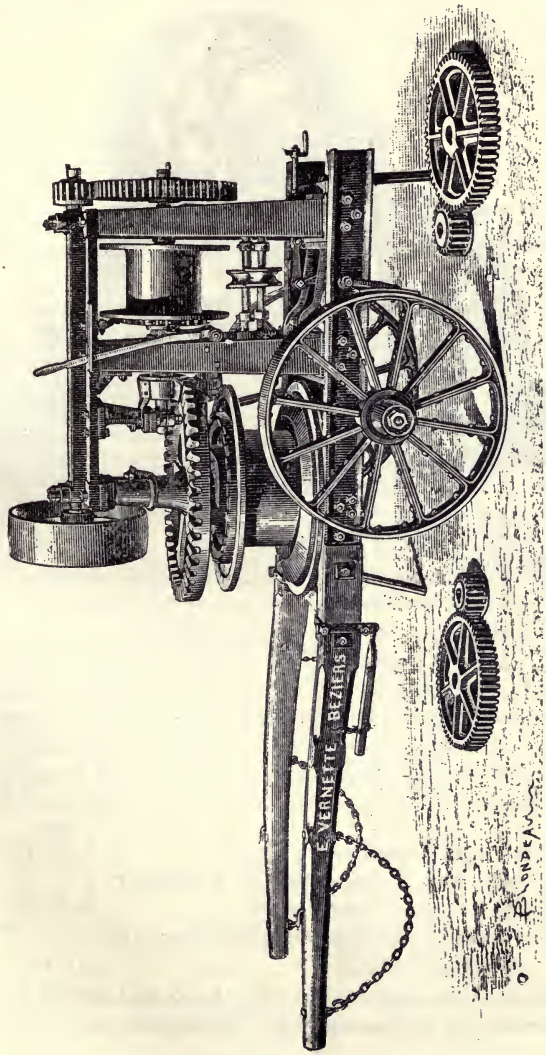


Fig. 77. — Vernette's Winding Drum, latest pattern, with Return Drum.

Fig. 78 represents a stationary winding drum with a small drum for the return cable (Pelous). The shaft of the pulley bears a bevel pinion, gearing with a bevel cog-wheel on a vertical shaft, bearing a double cog-wheel which may be alternately thrown into gear with either drum by means of a lever.

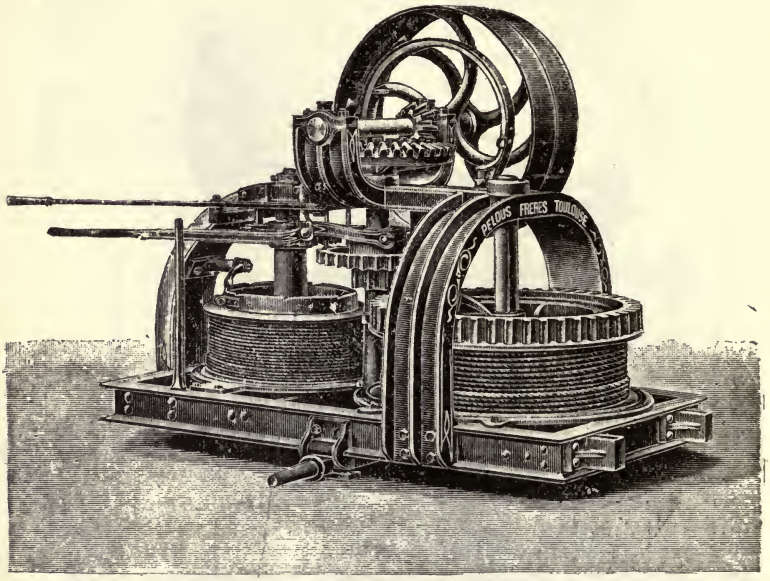


Fig. 78.—Pelous' Capstan with Drum for the Return Cable.

With a Beauquesne simple winding drum, as worked with an 8 H.P. portable engine at Mr. Deltil's property at Saint-Sulpice-de-la-Pointe (Tarn)*, the work practically done has been 3 furrows 219 yards in length, 19½ inches in depth, and 27½ inches in width per hour, *i.e.*, 16·8 poles per hour.

From many observations we may admit in practice the following figures relative to the analysis of a day's work :—

	Ratio.
27 per cent., meals and rest	43·4
11 per cent., anchoring and ordinary stoppages during work	17·7
62 per cent. useful work (ploughing and hauling back)	100·0

We may compare simple effect against double effect winding drums, working a balance plough backwards and forwards,

* *Journal d'Agriculture Pratique*, 1889, vol. 1., p. 578.

in the case where both are worked by steam. By taking the figures corresponding to the conditions we indicated for drums worked by horse power, we obtain the following results, limiting the duration of work to 200 or 210 days per year :—

Description.	Winding Drum.	
	Simple Effect.	Double Effect.
General Items—		
Cost of complete material*	£400	£600
Writing off in ten years, cost of repairs estimated at 20 per cent....	£80	£120
Power of the engine	8 H.P.	10 H.P.
Coal consumed per day	704 lbs.	880 lbs.
Time required in practice for the ploughing of 1 acre	$2\frac{2}{5}$ days	$1\frac{4}{5}$ day
Cost of work per day—		
1 engine-driver	4s. 9d.	4s. 9d.
2 workmen, at 2s. 4½d.	4s. 9d.	...
3 men, at 2s. 4½d.	...	7s. 1½d.
1 pair of bullocks for hauling back	4s. 9d.	...
Coal, at £1 12s. per ton	10s. 1d.	12s. 8d.
Oil, grease, and cottton waste	1s. 7d.	2s.
Transport of water and coal, 2 bullocks and 1 man, for a few hours	4s. 9d.	4s. 9d.
Total	30s 8d.	31s. 3½d.
Cost per acre	£2 9s. 3d.	£1 18s. 0d.

Area ploughed per Year.	Number of days worked per Year.	Cost per Acre.			Number of days worked per Year.	Cost per Acre.		
		Amount written off and Repairs.	Work.	Total.		Amount written off and Repairs.	Work.	Total.
		£ s. d.	£ s. d.	£ s. d.		£ s. d.	£ s.	£ s. d.
25 acres	40	3 4 0	...	9 8 9	30	4 16 0	...	9 11 0
50 ,,	80	1 12 0	...	7 16 9	60	2 8 0	...	7 3 0
75 ,,	120	1 1 4	6 4 9	7 6 1	90	1 12 0	...	6 7 0
100 ,,	160	0 16 0	...	7 0 9	120	1 4 0	4 15	5 19 0
125 ,,	200	0 12 8	...	6 17 5	150	0 19 2	...	5 14 2
150 ,,	...	...	...	...	180	0 16 0	...	5 11 0
175 ,,	...	...	...	...	210	0 13 10	...	5 8 10

* We assume in this case the engine to be solely used for this work, and bearing all the cost of writing off.

This table (which may be modified according to circumstances) shows that when an area exceeding 70 to 100 acres is ploughed annually, it is more economical to use a double-effect drum hauling a balance-plough. We will have an opportunity later on of comparing these figures with those of the steam winding drum engine (Fowler) often used by contractors.

III.

PRACTICAL INSTRUCTIONS REGARDING THE USE OF STEAM WINDING DRUMS FOR PLOUGHING AND TRENCHING.*

By A. Debains.

The necessity of reconstituting vineyards destroyed by phylloxera, attracted the attention of viticulturists to all systems of powerful appliances capable of disturbing land deeply. *Deep stirring of the land is, as a matter of fact, absolutely necessary to success in planting American vines*, to allow their roots to penetrate into the lower layers of the disturbed soil, which retains the rain water of the winter, preserving the roots against the detrimental effects of summer droughts. Many viticulturists, when their trenching or subsoiling is finished, abandon their winding drums without any care under sheds, &c., where they rust and soon become only fit for sale as old iron. If, on the contrary, these machines are well looked after, and kept in repair, they may be used for ordinary hoeing and ploughing of vines, as we will show further on; and later on, when it is desired to plant vines again they may be used as originally intended.

To thoroughly understand the management of a winding drum, and to utilize it to the utmost, we must have a good knowledge of the different parts of which it consists. We will study these briefly. We will not study here the heavy powerful double-effect steam winding drums, which are only used on large properties or by contractors. The practical machine for a medium grower is that which can be worked by an ordinary portable engine, as usually found on a farm, in use for pumping water, chaff-cutting, threshing, sawing wood, &c. With the object of simplifying the system and reducing the initial outlay, vine-growers almost blindly rushed after simple-effect drum machines, that is to say, those in which the plough is hauled back by a horse. If this system may be applied to cheap drums worked by a horse, it is no longer rational when steam-power is used, and if the advocates of the simple drums bring forward the argument of the difficulty or even the impossibility of anchoring the

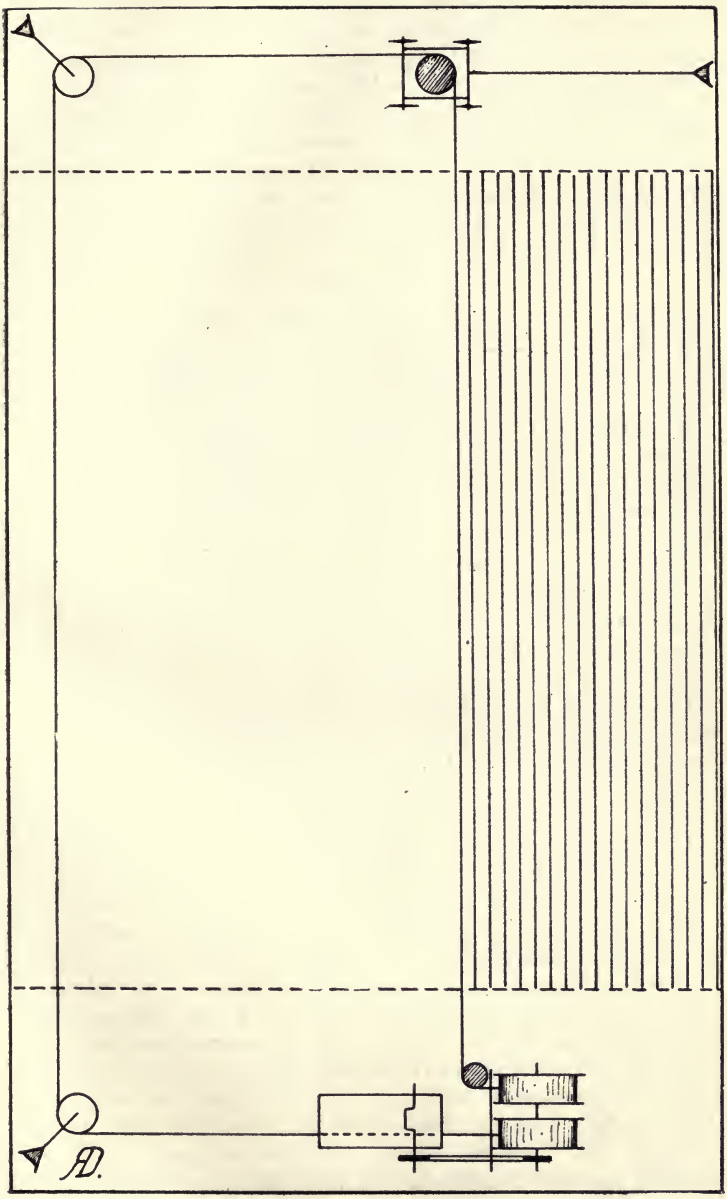
* *Revue de Viticulture.*—Vol. III., 1895.

fixed pulley, that is simply a confession of their ignorance as to the methods of effecting it, and we will insist on the essential conditions, which are simple and practical to anyone who has knowledge of that kind of work.

With the object always of reducing cost, implement makers when constructing double-effect winding drums only use a small simple pulley for the return cable. This pulley is kept in position by means of a chain made with large links, through which a peg, passing through the links of another chain, is fixed in a direction parallel to the opposite headland. The latter chain must be securely fixed at both extremities to anchors or wooden beams held by pegs. When the plough has opened two or three furrows, the peg is taken out, the pulley and the cable shifted by hand, which requires considerable effort, especially if the ground is wet; the peg is then replaced in another link of the chain. The latter must be securely anchored, as the effort it bears is double that of the direct traction, but, as implement makers seemingly wanted to increase the difficulties of anchoring, they made pulleys too small in diameter, and supported by a too narrow plate, which tends to come out of the ground when the plough starts. This system can only work satisfactorily with pulleys of a very large diameter, revolving on a very wide plate of wood or iron, but then it is heavy, and consequently difficult to move by hand.

The best method of securing the return cable is undoubtedly a large pulley, supported by a truck, provided with four steel discs cutting into the ground and preventing sliding. Plate X. shows the solution of this difficulty. It is certainly rather expensive, but it enables the work to be done easily without stoppages, a greater area to be ploughed, and consequently the cost per acre reduced.

The engine, behind which is the winding drum carried on its frame, travels against one of the boundaries. A pulley is anchored at a distance of 109 yards in front. The automatic anchor, having in its centre a large pulley, travels on the opposite headland. A third pulley is anchored in front of the automatic anchor. The winding system is made with two drums, one hauling the plough directly from the automatic anchor towards the engine, the other pulling it back after passing over the three pulleys. With this arrangement the strain on the automatic anchor is only one of the



components of the total traction, if the soil is dry this automatic anchor cannot slip, as it is kept in the soil by the discs cutting into it; and, if its weight is not sufficient, it may be increased by means of boxes filled with earth. If the portable engine and winding drum carriage are carried on iron rails, allowing easy displacement by block and tackle, the fixed pulley in front may be dispensed with, and the cable passed over the pulley in front of the automatic anchor, but in this case the pulley must be secured by two or three anchors, for, the angle of the cable being more acute, the strain on the pulley is greater.

The system being established as above, or in a similar manner, it remains to study the conditions which the different parts are to fulfil to obtain the best work. We will first study the winding drums. In double-effect systems one cable winds over one drum hauling the plough, while the other cable unwinds. This unwinding is irregular, especially if the soil is dry and stony. The plough proceeds by jerks; the return cable unwinds spasmodically, and may get entangled between the flanges of the drums or the gearing mechanism. To avoid this trouble the drums must be provided with brakes, acting slightly but steadily during the unwinding. One of the simplest systems of brakes is that shown in Fig. 79. It is made of a circular band of flat iron *e* terminated at both ends by two pieces at right angles, carrying at their extremities two threaded holes in which a thumb-screw V works. The flat iron bar carries inside wooden shoes *b*, and outside cleats *t*, rounded on one side and flat on the other. The shoes *b* rest on a circle provided with a flange fixed on the drum T or cast with it, upon which the pressure of the brake acts. When the drum T revolves in the direction of the arrow (position 1), that is to say, unwinds the cable, one of the cleats *t* comes in contact with the stop *m*, held in position by a cast-iron support bolted on the frame, and the brake acts. If, on the contrary, the drum T revolves in the opposite direction (towards the plough), one of the cleats *t* comes in contact on its rounded part with the stop, which is lifted (position 2), and the brake does not act. The lever *k* allows the stop *m* to be lifted by hand, and the brake to remain free. This is done when a certain length of cable has to be unwound by hand.

It is also necessary to make the hauling cable wind regularly round the winding drum. Most of the winding drums on the market are not provided with winding guides;

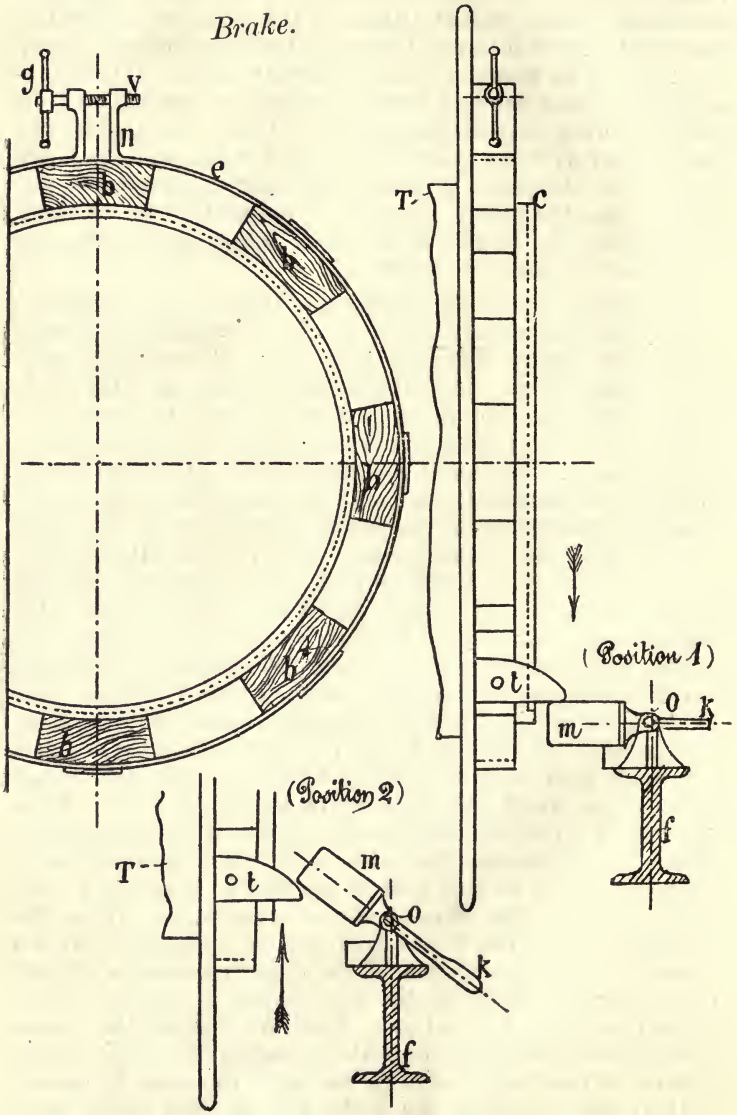


Fig. 79.—Diagram of Brake for Winding Drums

this is the main cause of the breakage of drum flanges and of the wear of the cable, the strands of which overlap each other, become tangled, and cause distortion, flattening, &c. In the machines designed for medium-sized properties, where the proprietor wishes to avoid complicated machinery, it is difficult to provide drums with winding guides (costly and cumbersome), such as those of Fowler and Howard; but it is always easy to attach that shown in Fig. 80, which costs very little to keep in repair, as the part subject to most wear is easily replaceable, and only costs 4s. 10d.

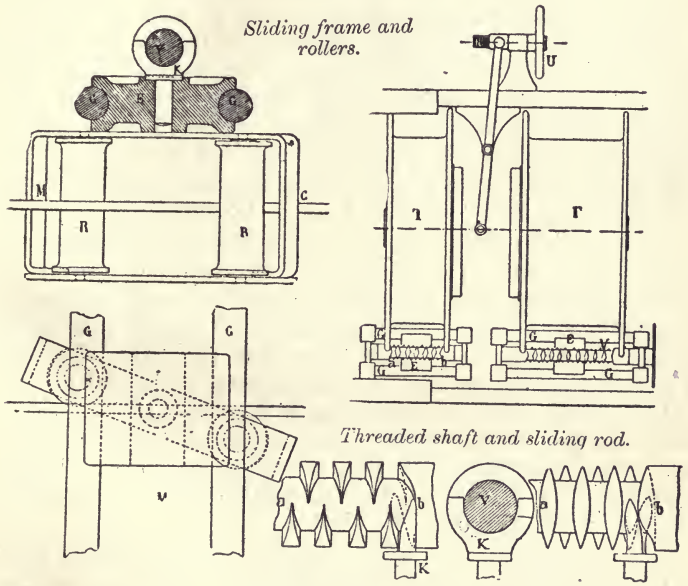


Fig. 80.—Winding Guide.

The principal part of the mechanism of this winding guide is a shaft V, round which two threads are cut in opposite directions, and opposite each drum, one winding to the right, the other to the left. Above the shaft, and parallel to it, are two cylindrical rods G serving as guides to a sliding frame M, carrying inside it two steel rollers RR and on the upper part the brass collar K. This collar revolves freely in a block E, through which the rods G pass, on which the block slides. Therefore it plays the part of a nut, and moves

in the direction of the thread on the shaft, guiding it, and with them the block E and the rollers RR, between which the cable C runs.

The space between the rollers RR, projected on a plane perpendicular to the cable, is exactly the diameter of the cable, but the space is greater in any other direction, so as to allow the free passage of any irregularity or splice in the cable preventing the rollers from being torn away.

The winding guide works as follows :—Let us assume the machine starting when the rod K is in *a*; this arm comes in contact with the thread of this shaft, and its speed is calculated so that the guide M travels at each turn of the drum a distance equal to the diameter of the cable. When the rod K reaches *b*, it is arrested by a block *b* on the threaded shaft V. The stop forces it to pivot round and engage the other thread. It then travels in the reverse direction, carrying the guide M; the rod then meets the stop *a*, pivots and returns, and so on until the winding of the cable is completed. The rod K is made of bronze, and wears out more rapidly than the steel screw, but is easily replaced.

The cable being the principal cause of the expense in steam ploughing it is necessary to take every precaution to diminish its wear, and, for this purpose, to support the cable on pulleys, so that it is only submitted to rolling friction. When the cable unwinds it is necessary to pass it over a pulley placed near the drum, as it has a tendency to come out of the groove on account of irregularities in the unwinding. A good method of keeping the cable in position consists in placing a small roller *r* in front of the pulley P, entering slightly into the groove (Fig. 82).

It is not sufficient to protect the cable against sliding friction on the frame of the drum ; it must also be protected against friction on the ground. This is prevented by cable runners. Most of the old systems used for cable supports were not practical ; they could only be kept in certain positions, and were very unsteady when the cable was being moved from furrow to furrow. The cable runner shown in Fig. 81 has proved satisfactory in practice. It is a small truck on three wheels, on which is a frame, carrying four rollers on top; two have a vertical axis, the two other rollers revolving horizontally ; and they are arranged in such a way that the juxtaposition of the groove of the four rollers forms a complete circle. The axle of the top roller can pivot round the spindle

A to allow the introduction of the cable *c*, which in any position slides on a roller. The axles of the three wheels are always parallel to the cable, which travels laterally with them.

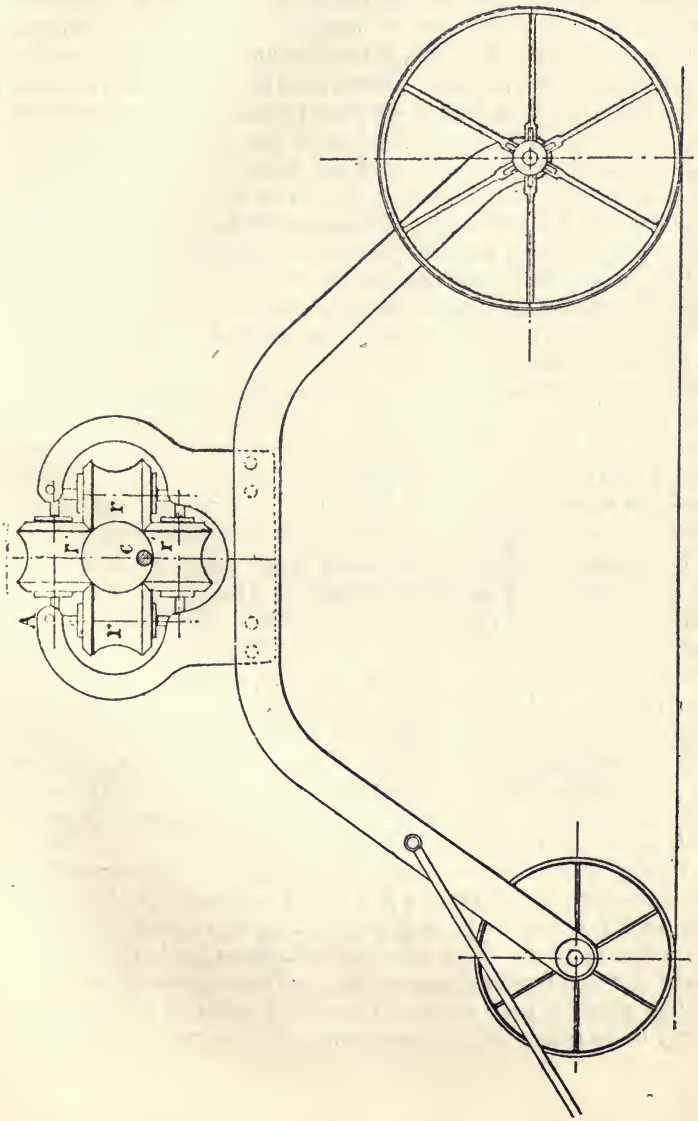


Fig. 81.—Cable Runner or Carrier.

We have already shown that a double-effect drum does the work per acre at less cost than a single-effect drum, the only troublesome point in the former being the anchoring of the fixed pulley. The steel anchors with two spikes give the best results, but they require to be strongly fixed, and many persons do not know how to manage them. We must not hesitate to place two or three behind each other joined by chains, if necessary. Moreover, if it rains during the night they must be pulled out and refixed. The anchors are completely sunk in the ground, and each of the spikes must be stayed by cross pegs *t t* (Fig. 82); the direction of the anchor must be carefully ascertained, as its position has great importance on their fixity. This is arrived at by an invariable rule; the line *m n* passing by the point of application of the pulley, must form equal angles α α, with the two parts of the cable passing over the pulley. The workmen find it by the following simple and practical method:—A rod 8 feet in length is taken, and one end placed in *i*, the point of intersection of the two parts of the cable; the distance the rod reaches in each direction is marked off, the two points joined by a rope and the point of the centre *o* determined. The direction *o i* is the direction sought. This method applies to any system of anchoring, for, when beams are used, they must be placed perpendicular to that line.

The fixed pulleys should be of large diameter, and fixed on wide plates. Fig. 82 represents a strong type of suitable dimensions. The pulley P is 33½ inches in diameter, and has a groove 2⅓ inches deep; it is thicker near the pivot, which is slightly conical, and has an average diameter of $2\frac{1}{10}$ inches. This pivot A traverses an iron plate *q r* slightly countersunk and inclined towards *q* and an oak plate 19½ inches wide, 3ft. 3in. long, 3 inches thick, strengthened on the side by two iron plates *f' f*, bolted through at *p p'*. The pivot A is held by a nut *e*, taking in at the same time a flat iron piece 2⅓ inches in width, *c c'*.

This piece *c c'* is bent and rounded at *c'* to a distance level with the top of the pivot; a piece *d* terminated by a hook fits on it; a pin keeps the piece *d* on the pivot A, another *g'* on the piece *c'*. This piece is indispensable to prevent the pivot A from bending under the traction of the cable.

The piece *d* may revolve round the pivot A to allow the cable to be taken out of the sheave. At the rear, a V-shaped

piece *k* is fixed over the piece *c'*. The chain of the anchor S is fastened to it. A block of wood 2 inches thick, fixed under and in front of B supports the pulley P, and prevents its axle from bending under the effort or traction, and at the same time protects the nut *e* when the pulley slides on the ground.

It is important to have several other simple tools on the spot—a spade, a pick, a sledge-hammer, a hammer, a spanner, and iron pegs—it is also necessary to have a lever to use, even in very wet soils, in order to dislodge the wheels or discs of the automatic anchors. The instrument shown (Fig. 82) answers this purpose. A wooden lever L, 8 feet in length, is terminated by an iron piece *a*, in the hole of which a double chain is fixed with hooks at each end; the lever can be raised or lowered between the branches of the piece B made of flat iron, bolted on a wide bed-plate S. The chain *c*

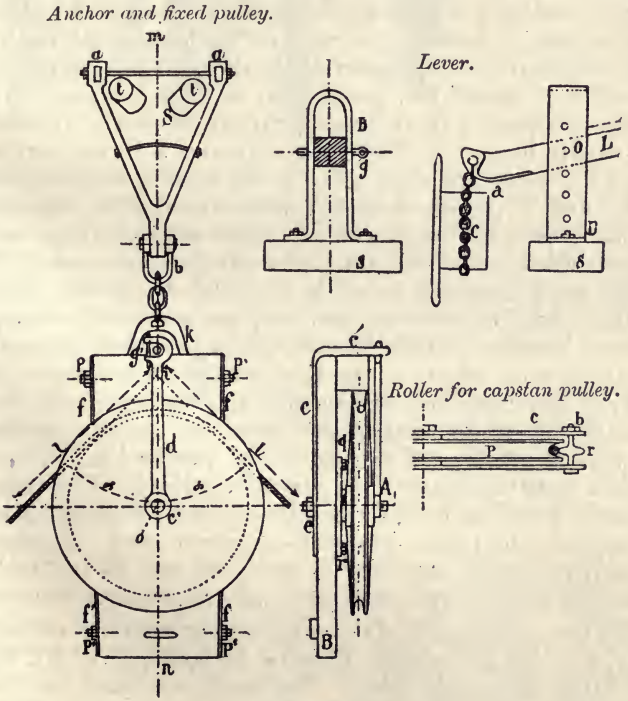


Fig. 82.—Accessories.

is fixed round the box of the wheel to be raised, and a man acting on the other end of the lever *k* may easily lift very heavy weights ; this instrument is more practicable than an ordinary screw-jack, which could not be used in very damp soils.

The most delicate and costly part of a subsoiling plant is the cable. Its strength and quality must be tested before purchasing it. The only cables used now are those made of steel wire, the diameter of which varies from ½ inch to 0·86 inch. Above 0·86 inch they become too rigid, and do not wind easily around the drums. They are generally made of four strands, each of which is again divided into four strands twisted around a hemp cord. Each cable must be, when purchased, wound on *very strong* portable drums, for, if these drums break, it is very difficult and sometimes impossible to unwind the cable, which has, consequently, to be cut in many places, rendering it afterwards weaker. These cables must be very regular in diameter, supple, yet not extensible, for when they lengthen their diameter diminishes. They should resist an effort of 25,800 lbs. per square inch of section. When working normally their breaking strain should be 51,600 lbs. per square inch. In clay or clay-siliceous soils they are supposed to work 150 days of 10 hours with a steam-winding drum and a plough working at the rate of 15½ inches per second ; and 450 days with a horse-winding drum and a plough working at the rate of 4 inches per second. The cables are guaranteed to work the above number of days, on the condition, however, that they are not made to support a strain greater than 25,800 lbs. per square inch of section, for above this effort of traction, which is the limit of elasticity of the cable, it will lengthen and dislocate. Notwithstanding every precaution, the cable may become entangled between the flanges of the drum and get broken. The two broken ends then have to be carefully spliced. This splicing requires great care and special tools, which should always be kept on the place—two well-tempered steel cold-chisels, a marline spike, made of a steel rod 0·6 to 0·8 inch in diameter, well sharpened at one end, and a strong hammer.

The two broken ends of the cable are cut with the cold-chisel (Fig. 83), the strands are unlayed for a length of 3ft. 10in., and fitted into each other. The ends are laced over and under the strands of the opposite rope, as shown in Fig. 83,

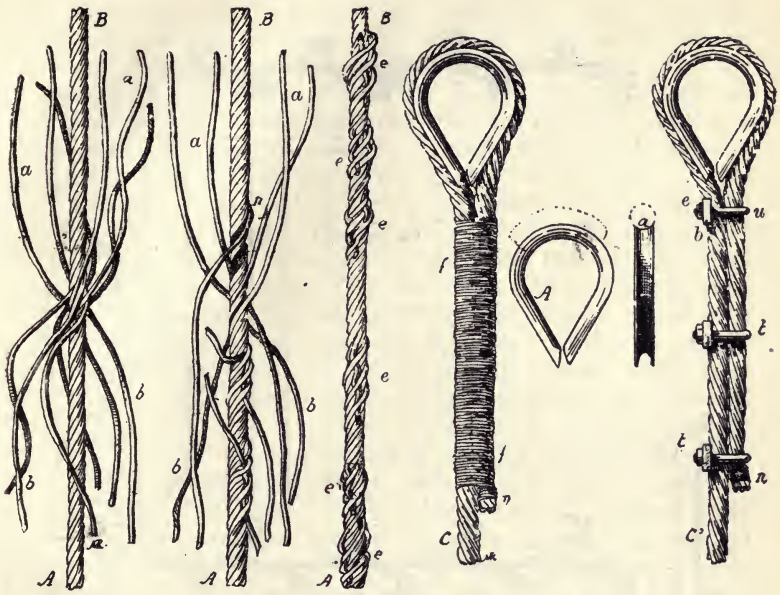


Fig. 83.—Splicing.

untwisting a little with the aid of a marline spike. The four ends must be left projecting 1 to 1½ inches ; if not, the splicing would not hold. When the splice passes over the drum for the first time, the rollers must be left a little wider, otherwise it might tear the cable ; this precaution is often overlooked, and is the cause of frequent accidents. The loose ends of the strands get flattened against the cable after the first winding.

We have insisted on these small details in working subsoiling plants, because all these precautions are indispensable, and it is almost always because viticulturists have neglected them, that they find some difficulty in working these machines, and are often stopped in the course of the work.

Many viticulturists wonder what can be done with these expensive machines after they have finished trenching work, as they often still remain in very good order. Those who possess these machines will find great advantage in utilizing them to perform the yearly ploughing of their vineyards, especially if the vines have been planted well apart (5 feet to 8 feet).

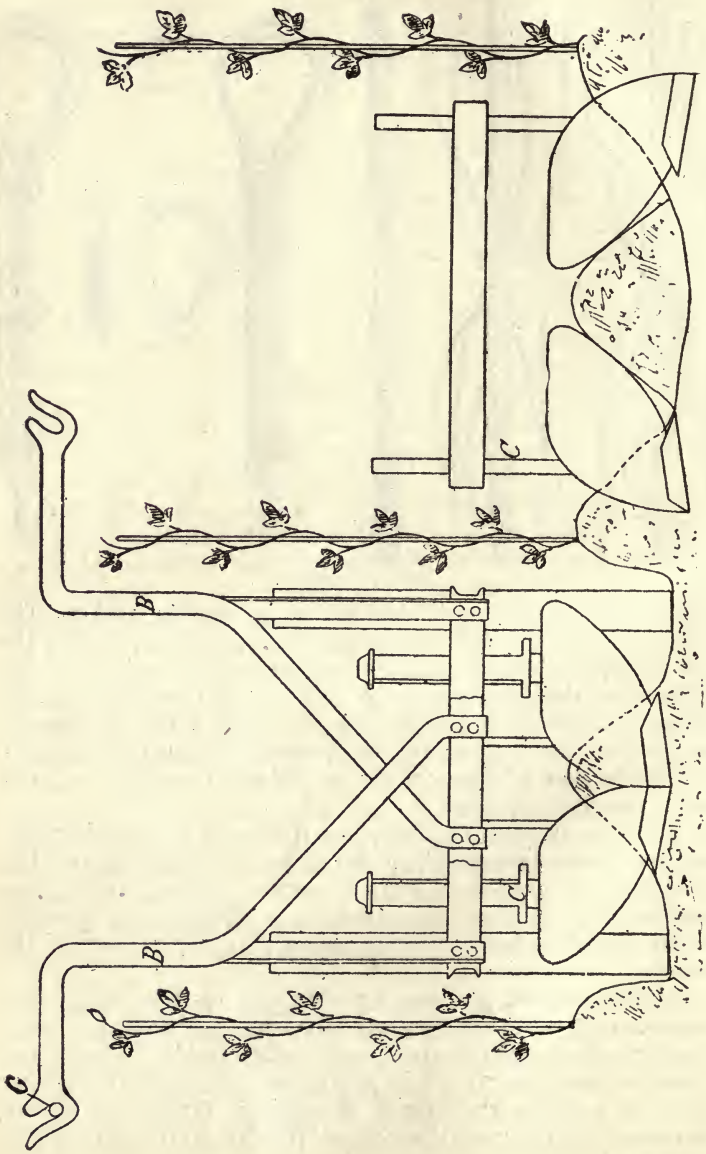


Fig. 84. — Bajac's Steam Plough for vineyard cultivation.

This is possible by using special ploughs, which are made after the fashion of steam-cultivators. These machines were invented and patented in France, and constructed in England by Fowler, and in France by Bajac. They are made of a very resistant iron frame, rounded at the rear, and narrowed between the wheels, strongly braced with double braces, between which the bodies of the implement are fixed.

The bodies of the plough may be fixed in four different positions lengthways ; the mould-boards may be so arranged as to throw the soil towards the centre or towards the outside (Fig. 84). During this work the vines must be protected against any friction from the cable which might pull down the stakes, or break the stumps. With this object, two arms B are fixed on the frame, and their width may vary so as to bring the cable on the outside of the next row of vines. The return cable is placed by the ploughman with the aid of a special mechanism at the end of the arm B, and, when the plough proceeds, it unwinds and places it between the next row of vines. With this system, the return cable becomes the traction cable ; when the plough has reached the end of the row, the cable is simply thrown on the ground, the plough pivoted round the wheel nearest the ploughed part, and started in a new row, in an opposite direction ; the other cable is lifted on the corresponding arm, and while the plough proceeds, it is placed between the next rows as in the first instance, ready for the return.

Many of these ploughs are working in Algeria, and are giving excellent results. They enable vignerons to plough between vines to a great depth, which has the advantage of allowing the water to reach the subsoil, thus keeping the soil moist during summer droughts.

With these machines, vine-growers will be able, not only to create and reconstitute vineyards, but also to use their winding-plant all the year round.

IV.

THE ADVANTAGES OF STEAM CULTIVATION.

By Prof. John Scott.*

The advantages resulting from the employment of steam-power in tillage operations are now generally recognised. One chief advantage is that it renders the farmer comparatively independent of labour; at all times he has an enormous power at his command on a moment's notice, and is thus able to deal with the land when in a fit state for cultivation. Another great advantage is that when the ordinary operations of breaking-up are done at the proper season, it will be found that no mechanical pulverization is required. The rapid motion of a steam-driven implement tears and breaks up the land so that it remains in a loose, rough state, and the atmosphere, acting upon the subsoil as well as on the upper part of the staple, permanently raises the temperature, pulverizes the whole by degrees, and thoroughly prepares it for the reception of the seed. All injurious treading by animals is avoided, and the roots of plants can easily penetrate to the subsoil.

In estimating the expense of steam cultivation few justly appreciate the great change that it effects in the character of the soil, both as regards the drainage and the cost of after tillage. When land has been once thoroughly broken up by steam, every succeeding operation requires less power; and the experience of those who have used steam-power proves that one-half only of the usual operations is required.

The value of steam tillage has been well exemplified from another point of view in droughty autumns. In very dry seasons, such as 1865, 1868, and 1870, after all harvest operations were concluded, the stubbles were so hard and dry that many farmers were compelled to wait for rain before they could be ploughed by horses, whereas, those who had the steam plough got to work at once, and had large breadths of land broken up and cleaned in the most efficient manner, the result of this thorough cleaning and tillage being most apparent in future crops.

There are now ploughing engines capable of exerting 100 indicated horse-power, and capable of putting a draught of 3 or 4 tons upon an implement at a rate varying between 3

* *Text Book on Farm Engineering*, 1885.

and 4 miles an hour. With such power any reasonable depth can be reached, and as the disintegrating power is, by a well-established mechanical law, as the square of the velocity, the soil is broken up with four times the mechanical effect at 4 miles an hour, as in the case of a horse-drawn plough at 2 miles an hour.

In the words of the carefully-considered report of the committee of the Royal Agricultural Society on steam cultivation (1867)—"A culture deeper than it is possible for horses to effect works a highly beneficial change in the texture of the soil, imparts additional efficiency to drainage works, augments the value of the manure applied, brings into operation certain latent properties of the soil which much increases its fertility; and it also fits land formerly unfit for the growth of turnips, allows of their being fed off by sheep, the operations of the field are economized, and the growth of all crops is stimulated."

"These are," says *Engineering*, "the remarks of a committee who had been labouring industriously for months in examining the results of steam cultivation upon nearly 200 steam-tilled farms in all parts of England and in some parts of Scotland, and are simply the deductions of the best experience. At the time of their report steam tillage was not only better but was considerably cheaper than horse tillage. Now, the steam-engine, rope, and other tackle and the attached implements have been very much improved, and the comparison would be still more in favour of steam. It would be something to save 2s. or 3s. per acre upon the 10,000,000 acres of tillage land in England yearly, and experience shows that this saving of £1,000,000 to £1,500,000 can certainly be accomplished. But the greatest gain is in the improved crops, due to thorough tillage, and this may amount to an extra quarter of wheat, an extra 3 or 4 tons of turnips, or something equivalent, and, in this way, the average crop may be increased possibly to the extent of £10,000,000. There are many recorded instances of steam-ploughed fields yielding 2 or more quarters of wheat per acre more than they did under horse tillage."

No doubt the cause of steam tillage has suffered from an indiscriminate use of deep ploughing in certain instances, but that has been a misapplication of the power.

On the other hand, in addition to ploughing and cultivating, great benefit is found to follow the application of steam

power to the drilling and harrowing in of seeds on heavy soils, especially in wet seasons, as the injurious effects of trampling by horses is therefore avoided.

Systems of Steam Cultivation.

Of the many schemes and systems of steam cultivation which have been practically brought before the public two only (and those the simplest) have proved themselves successful. In both of these the traction power is transmitted to the implement through a steel wire rope winding upon a drum. In the one plan the two winding drums are fixed in a windlass frame, and connected to a stationary steam-engine, which can be worked from one corner of a field. One end of each rope being made fast to the plough, the implement is drawn backwards and forwards by the drum pulling alternately, and the pulley, sheaves, and anchors at each end of the furrow move forward as the implement proceeds. In the other system, each of the winding drums is placed under the boiler of a self-moving steam-engine, and one engine at each end of the furrow alternately pulls the plough towards it, while the other moves forward into position ready for the return. These two systems are known as the single-engine or roundabout, and the double-engine or direct method of steam cultivation.

In noticing these two methods of working we shall take the double-engine system first. It must be understood, however, that any method of steam cultivation must needs involve considerable modification in detail to work equally advantageously under all circumstances. Under most other machinery a steam cultivating apparatus is required to work under greatly varying conditions, and often under circumstances where nothing whatever has been done to assist its introduction. The general formation, the condition and requirements of the country, the nature of the soil, the size and arrangement of the holdings, and the available capital, are all items which influence the application of steam-ploughing machinery, and may demand important modifications in its construction.

The Double-Engine System.

Fowler's direct method of working is illustrated in Fig. 85. It includes two self-moving engines with winding drums, 800 yards of steel rope, and the necessary implements. The

engines are worked on opposite head lands, and each alternately draws the implement towards itself, the engine not in work paying out the rope while moving forward into position for the return journey. Any kind of implement may be used.

The advantages of this double-engine system are — the short length of the rope required, and consequent economy of power, the facility with which the machine is set to work and taken up, and the small amount of wear and tear, due to the simplicity of the tackle. Its disadvantages are its first cost, and the difficulty of moving the engines on very soft or wet land. The last difficulty has been, however, almost entirely removed by increasing the diameter of the driving wheels.

For large farms and for letting for hire this system is the best, and has proved itself capable

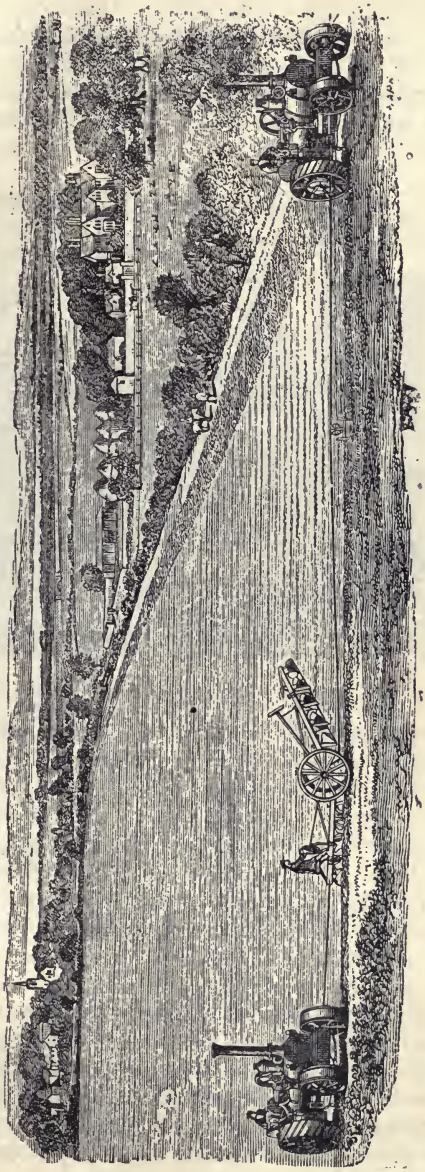


Fig. 85.—Fowler's Double-Engine System.

of doing more work per day at less cost than any other. Land can be ploughed by it at one-half the cost of horse-power.

Fig. 86 shows an engraving of Fowler's Single Cylinder Steam Ploughing Engine. These engines are made of 6, 10, 14, and 20 horse-power. They are constructed with single

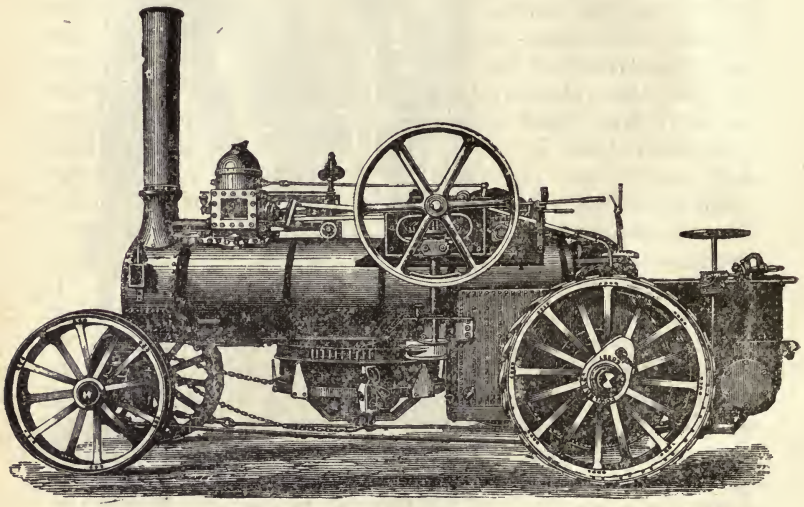


Fig. 86.—Fowler's Single Cylinder Steam Ploughing Engine.

steam-jacketed cylinders, and are provided with steam domes. The road-gear is constructed of spur-wheels, and made entirely of the best crucible steel. The road-wheels are wrought iron, from 16 to 24 inches wide. The engine has two travelling speeds, and is available as a traction-engine, and can be used for any agricultural purpose, such as threshing, pumping, grinding, sawing, or any operation of the kind. The power is conveyed to the winding drum by an upright shaft from the crank shaft. The winding apparatus consists of a horizontal drum, which, by means of coiling gear, winds and unwinds the wire rope uniformly without any attention from the man in charge. This is done by a self-acting lever, which carries two vertical guide pulleys, moving slowly up and down, and freely swinging round the drum into any position at which the rope has to work. By this means all strain on the rope, as well as on the apparatus, is avoided.

The Improved Single-engine System.

Howard's steam-ploughing machinery on the single-engine system is shown at work in Fig. 87. This is an improvement on the old single-engine or roundabout system, as the

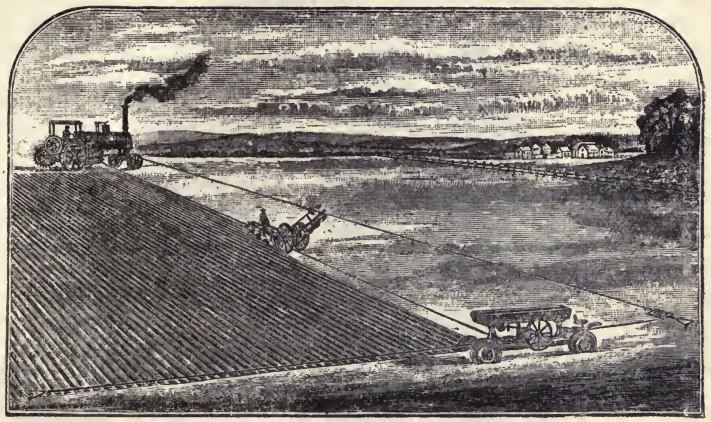


Fig. 87.—Single-engine System.

engine here employed (Howard's "Farmer's Engine" for ploughing on the single-engine system) is not stationary, but moves itself along one headland. The automatic anchor, which is remarkably simple and effective, moves along the opposite headland at each bout as the work proceeds. In this way much less time and labour are required to start work in the field than with any other single-engine system, and a shorter length of rope is used. Only two men, the engine-driver and the ploughman, with a lad for the rope porters, are employed.

The advantages of the single-engine system are in the comparative cheapness of the tackle, and in its superior fitness for very hilly or awkwardly shaped fields, as it can then be worked on the stationary or roundabout method with two automatic anchors. Its disadvantages consist in loss of power, great length of wire rope, wasteful expenditure of time in removals, and great quantity of apparatus necessary.

Implements used in Steam Cultivation.

The implements used in steam cultivation are all made on one of three principles :—

1. Balance implements.
2. Turning implements.
3. Implements which go backward and forward without either turning or lifting.

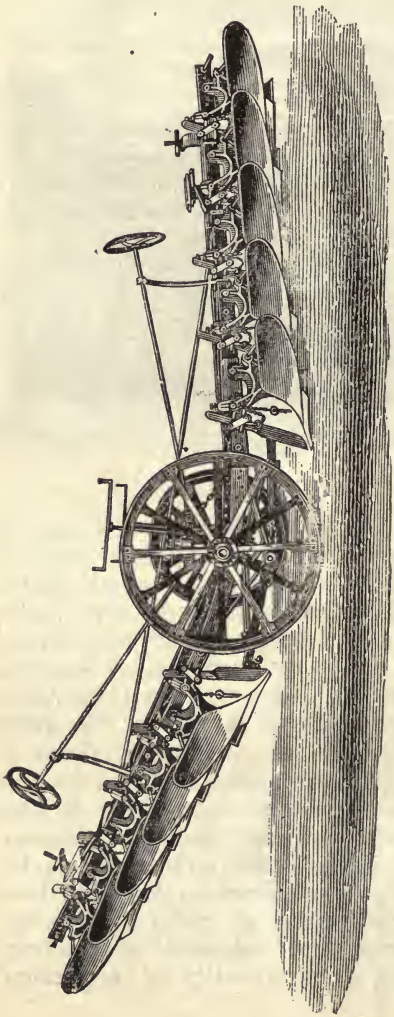


Fig. 88.—Balance Plough.

Balance Plough.

Fig. 88 represents Fowler's Patent Balance Plough, made for two to eight furrows, as circumstances may require, the construction of which has been considerably improved by the patented invention of the simple plan of always obtaining an adjustable width of furrow. The rigid iron frame, which is so essentially necessary to all steam-driven implements, is still maintained, and the alteration of the width of the furrows is effected by means of a wedge, which throws the ploughs at different angles to the frame. This wedge does away entirely with bolts and screws, and renders the position of the ploughs thoroughly rigid, at the same time is the best means of altering the width of the furrows. Several operations can be performed by this implement without much alteration.

The frame is so arranged that the shape of the ploughs and mould-boards can be varied to suit any circumstances that the land may require. Any class of mould-board can be supplied. By removing the ordinary mould-board used for surface ploughing, and substituting short ones, or "digging breasts," a tillage can be effected quite equal, if not superior, to spade husbandry, which leaves the land in the most desirable state for the action of the atmosphere. From the shares and mould-boards being attached on the outside of the beam all choking in very foul land is obviated.

In ploughing lea or other land for cereal crops, from the speed of the plough, the work done is sometimes rough and rather too loose, unless a land-presser or consolidator is attached to and drawn behind the plough. It is necessary to have the presser one furrow larger than the plough; by the use of the presser a firm seed-bed is secured.

Subsoil Plough.

This implement (Fig. 89) is constructed by J. Fowler and Co., and worked on the principle of a balance plough.

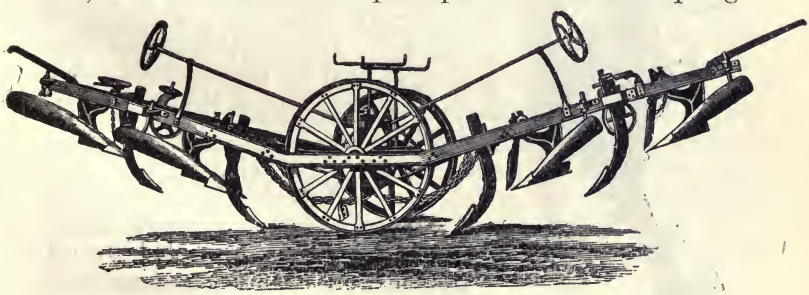


Fig. 89.—Subsoil Plough.

Besides the ordinary ploughs attached to it, it is fitted with tines, one tine following each plough and breaking up the subsoil to any required depth without throwing it on the top of the land. In some land it is simply ruinous to bring the subsoil at once to the surface. But by admitting the atmosphere it may be gradually prepared for this operation.

Sutherland Reclamation Plough.

This (Fig. 90) is also an implement invented by Fowler and Co., and has been much used by them in carrying out the Sutherland Reclamation works. It is so constructed

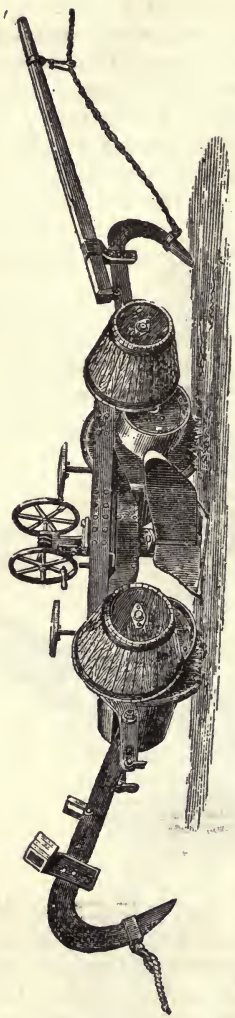


Fig. 90.—Sutherland Reclamation Plough.

that the most stony land can be cultivated without trouble or breakage. It will be seen from the engraving that it is preceded by steel discs, which lift the plough over the stones or obstructions so as not to break the mould-board. The plough will turn a furrow 2 feet wide by 15 inches deep completely over, and it will be observed that the turning of the furrow slice is not altogether effected by the mould-board, but is very materially assisted by the rollers, which catch it at the moment of leaving the plough. The stones which have been passed over are caught by the hook-tine, which comes behind the plough, and torn out. They are then removed by men. The tine thoroughly subsoils the land to a depth of 2 feet, and materially assists the drainage of the soil. This implement has been largely used for the last three years in the reclamation of land in Sutherland.

Turning Cultivator.

Fowler's Patent Turning Cultivator (Fig. 91) is adapted by all systems of steam-cultivating machinery. It consists of a strong iron frame, carrying, according to circumstances, from five to thirteen tines, and resting on three road-wheels, the front wheel being flanged and used for steering. The axle of the two hind wheels is cranked, so that by turning it the frame is lowered or raised, and the depth of the tines adjusted. The long end of the draft bar or "patent turning lever" is provided with two arms, to which the two ends of the ropes are attached. The arms are set at an angle to keep the tail rope clear of the implement. The lever itself

is held by a vertical stud fixed to the frame considerably behind the steering wheel. This position of the draft stud (the subject of a special patent) gives the necessary liberty

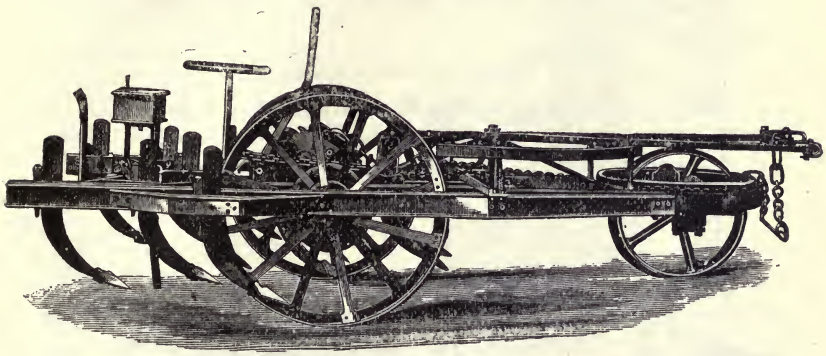


Fig. 91.—Turning Cultivator.

and power to the steering wheel, and enables it to lead the implement at almost any angle out of the line of the pulling rope. On the short end of the turning lever is a chain communicating with a quadrant on the crank axle, and as the lever is pulled round the chain acting on the quadrant turns the axle, lifts the frame, and raises the tines out of the ground. The plan of operation is as follows :—As soon as the cultivator is brought up to the headland the reverse pull brings the lever round and lifts the tines out of the ground, and they are held up by a catch ; when lifted the required height the lever strikes against a stop, and the implement turns into new ground ; the man (who never leaves his seat) releases the catch, the tines drop into the ground, and the implement is drawn across the field.

The principal advantages of this implement are as follows :—Its size is only limited by the power of the engines, which thus may be used to their utmost capacity. It smashes up the soil, working steadily, and always preserving a perfectly uniform depth. Even the largest implements of this description require only one man in attendance. In rounding round no additional work is required, and scarcely any time is lost, whilst the implement, however wide, at once moves into new land, leaving small and irregular headlands. On average soil 30 to 50 acres per day may be efficiently cultivated. Ridging bodies attached to the frame of the cultivator make an effective and easily handled ridging implement.

The ridging bodies are attached without taking away the tines, and both operations are done at the same time.

This implement is well suited for the last operation in autumn, as it effectually exposes the soil to the action of the atmosphere.

Grubber or Knifer.

This instrument (Fig. 92) is also one of Fowler's, and is extremely valuable on stiff clay land. By working it 2 feet deep, the subsoil can be stirred and aerated without at all

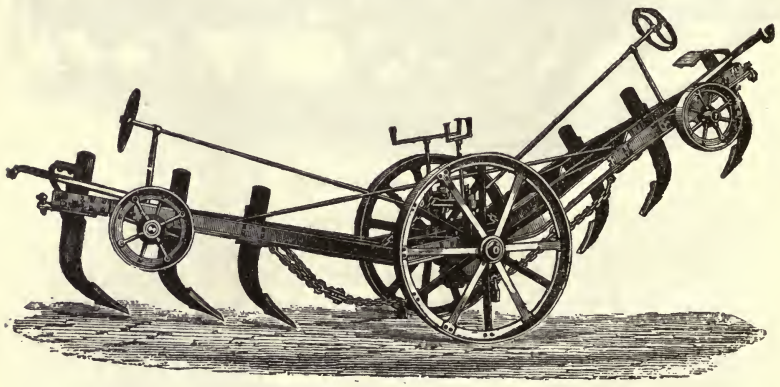


Fig. 92.—Grubber or Knifer.

interfering with the surface. The benefits which result from this operation are of the utmost importance. By its use the land is quite altered in its nature, and the advantage to the crops has been of very marked description. The drainage is also greatly assisted, and we wish to call the special attention of occupiers of clay land to this implement. It is made with one, two, or three tines.

It is also adapted for removing tree roots or stones, and can be worked 3 feet deep.

This is an excellent implement for stirring up the subsoil of old grass land, and to all owners of clay land is a decided advantage.

Turning Harrow.

Fowler's Patent Turning Harrow for steam cultivation is shown in Fig. 93. The difficulty occasioned by the ordinary cultivator turning up more callous stuff than is desirable in the spring of the year is entirely obviated by the use of this implement, which, it will be seen, is a combination of cultivator

and harrow, and is adapted for doing work which may be described as half-way between that effected by a cultivator and harrow, and superior to any horse cultivation.

Two kinds of shares are made for this implement—one a board share for cutting the whole ground, the other a square-pointed share for moving the soil only; but the requirements of the farmer will always determine which of these should be used. As a matter of economy, it is advisable to keep a complete set of tines and points of each kind always in stock.

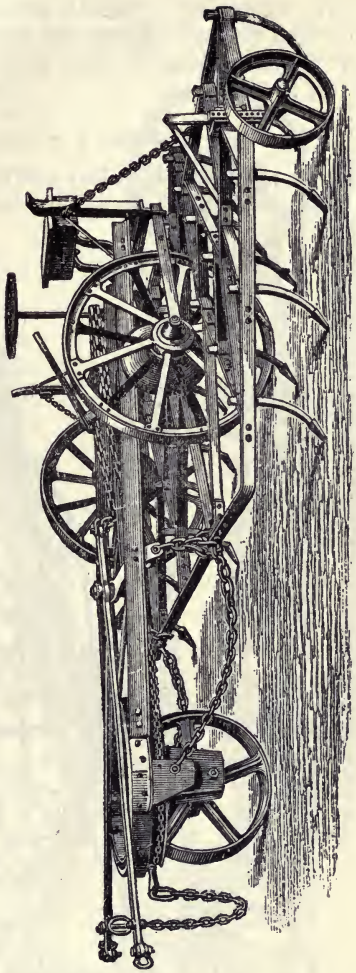


Fig. 93.—Turning Harrow.

This implement is constructed in three pieces so as to accommodate itself to uneven surfaces, and will take a breadth of 10 to 15 feet; it is especially designed to work on land that has been steam-ploughed, dug, or cultivated in the previous autumn, and it will do everything necessary in the spring to insure the land being in a proper state for any kind of crop. The steering frame is so arranged that it will take different harrows, from the lightest seed-harrow up to regular light cultivating tools; it also can be fitted with light ridging ploughs. In a similar way to the action of the cultivator previously described it is lifted at the end and turned round, thus getting into new work at once.

Three ridging bodies can be put on the steering frame by removing the harrow frame.

This exceedingly useful implement is made of wrought iron, with welded sockets for the tine.

A light harrow or any such implement can be hung behind it if desired.

Howard's Steam Harrows.

These harrows (Fig. 94) are very suitable for pulverizing and cleaning land after it has been broken up by the steam

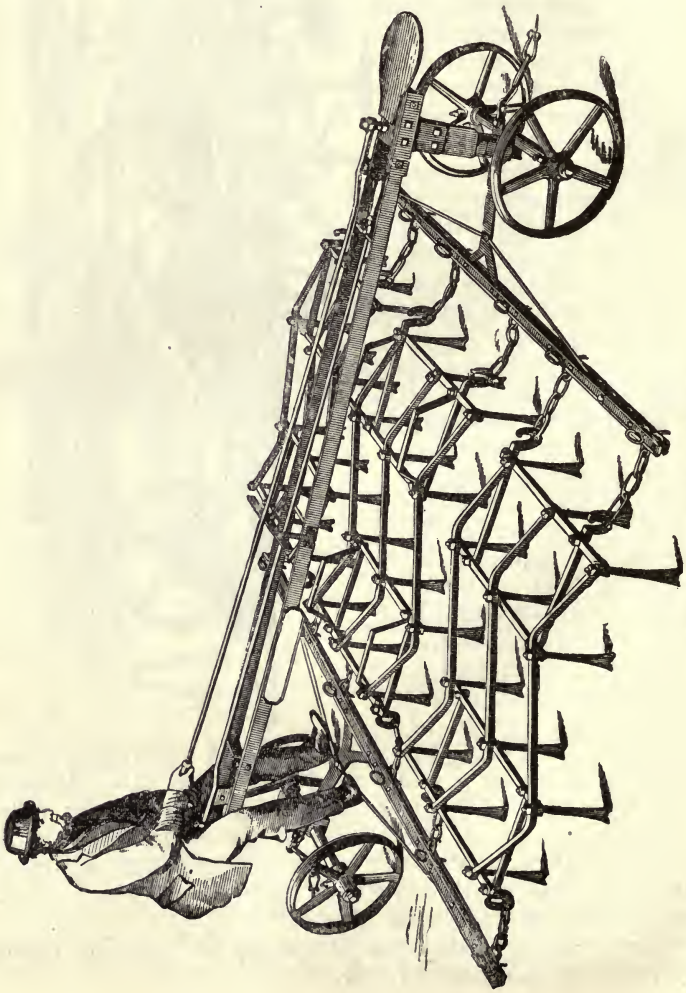


Fig. 94.—Howard's Steam Harrows.

cultivator. With "The Farmer's Engine," or the roundabout system, 15 to 20 acres may be harrowed in a day. The tines of the harrows, which are fitted with double-ended rocking-points, and which can be easily renewed when necessary, are made for drawing out the couch-grass or twitch without breaking it, so that it can be collected and burnt.

Fowler's Patent Discer.

This instrument is intended to cultivate newly reclaimed soil without tearing up the solid furrow and bringing the turfy matter to the top. It does this most effectively, merely pulverizing the top to a depth of 3 to 4 inches, and it leaves the turf at the bottom to rot, and considerably reduces the expense of pulverization for a crop. In moss and grass land this implement is invaluable, and it may be used with advantage in ordinary cultivation. It was first used in the Sutherland reclamations in 1876.

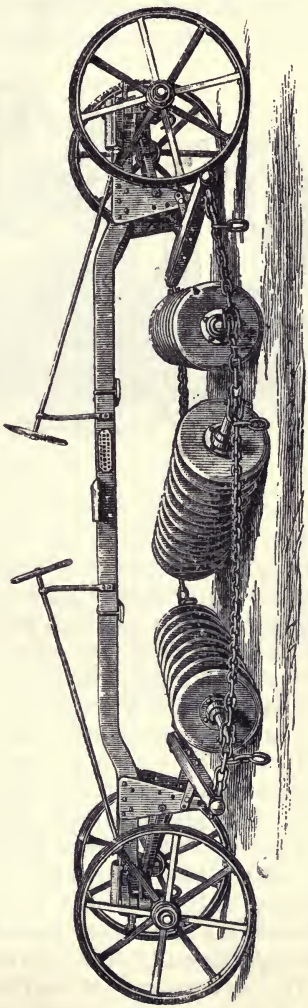


Fig. 95.—Fowler's Patent Discer.

The Discer (Fig. 95) has three axles, set askew to each other and to the line of draught, each of them carrying a number of thin discs, which revolve freely as the machine is drawn forward, cut the turf or peat to a few inches in depth, and throw the disintegrated mould into little furrows.

Steam Roller.

Fowler's Steam Roller, shown in Fig. 96, is made a total width of 15 feet, and may be fitted with any description of

roller, or with roller and harrows. The frame is hinged in the middle, and can be readily taken to pieces, so that, in moving from field to field, the two halves are pulled one behind the other, any difficulty in moving this broad implement about being thus effectually overcome.

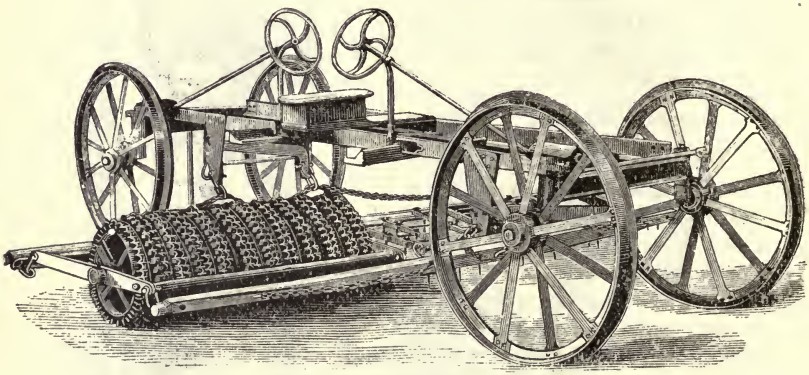


Fig. 96.—Steam Roller and Harrow.

Combined Steam Drill and Harrow.

The great drawback to steam drilling has been that even a drill of the largest width admissible under ordinary circumstances requires only a fraction of the power which is at the disposal of the engines generally supplied for cultivating operations. Only by combining other operations, such as light cultivating and harrowing with drilling, can the power be advantageously applied.

For this reason the steam drill is combined with a light cultivator or heavy harrow in front of the seed-coulter, and a light seed harrow following the same. Thus, three distinct operations are performed in going over the land once.

Fowler's Steam Drill has a total width of 9 feet. In turning round, the heavy harrows are lifted by the power of the engine, and the whole implement moves at once on new ground, the same mechanical principles being applied as in the turning cultivator previously described.

The advantages of this combination are very great, for when the land is prepared, 30 acres and upwards a day are efficiently drilled and harrowed without the trampling of the seed-bed with the horses' feet.

V.

PORTABLE WIND MOTORS APPLIED TO TRENCHING AND SUBSOILING.*

By M. Charvet.

Wind.

Wind is the more or less rapid movement of translation communicated to different parts of the atmosphere. It is generally assumed that this phenomenon is due to the variations in density of different masses of air under the influence of heat or cold. The air of cool regions travels towards warmer regions, hence those huge currents, some of which are constant and periodical, *trade winds;* and others, variable, such as those often observed inland.

The configuration of the country has a powerful influence on the direction of the winds, at least for the lower strata, which alone are utilized by the wind motors in actual use. Mountain ranges, forests, river valleys, break atmospheric currents, and deflect the direction they would follow under the action of the causes which produced them, distributing them in all directions. Therefore, the study of wind currents is a very complex question, when it applies to a large tract of country. If, on the contrary, it is restricted to a small locality it becomes simpler, and may in many cases furnish useful indications for the construction and establishment of wind motors. In a certain spot, every year, at the same time, the winds will recur with the same speed and the same direction, as the obstacles deflecting them remain, and that the causes producing them recur periodically with the seasons.

It is in this state of variations that agricultural industries must take the wind to utilize it as a motive power. The mechanical arrangements of the motors should be suited to the variations, not only of direction, but also of intensity. As the causes disturbing the equilibrium of atmospherical columns are essentially variable, it naturally follows that the effect, that is to say the rate of speed of the air producing the motive power, is also variable.

The regions where these motors will be used with the greatest advantage are plains, or summits in hilly countries, sometimes even in certain positions at the entrance or exit

* *Le Progrès Agricole et Viticole.* Vol. 17, 1892.

of a valley. There the winds follow their natural movement without encountering any obstacles ; or the configuration of the surrounding country may be such as to send many winds from different points of the compass in one direction; this should be chosen to install a motor. The Mediterranean region is favoured as much as the plains of Holland as far as the constancy and frequence of wind are concerned, and the results of meteorological observation, which will be given subsequently, allow us to estimate the number of days such a motor may be worked.

The natural forces, such as water or wind, are gratuitous forces, as is often remarked. These forces, it is true, do not cost anything, but they must be mastered and transformed, and the motor used for their transformation and application of it to a certain class of work represents a certain amount of capital which must be written off ; the presence of a man is also necessary for the supervision of the machine. That is why wind, of all motive power, is generally the last to which recourse is had, for industrial or agricultural operations, for it is too capricious ; but we must acknowledge that such a motive power presents economic advantages, for the power is spread naturally over a great area. On a large plain the number of the points upon which that force may be rendered available is considerable.

If it is preferable to utilize a water-course whenever the opportunity exists, on account of the great regularity, it is nevertheless true that a wind motor has the advantage of being erectable in any point of the region and more so in large plains, generally deficient in water, where the wind blows with great force ; and Lucet's motor has the advantage of being very portable.

This could not apply to the use of water as a motive power, but water can be carried to the motor, its force adjusted so as to obtain regular work. In the case of wind this, however, does not apply. We must take it as it comes, both in force and direction.

Utilization of the Motive Power of Wind.

In all mechanical operations requiring constant and regular motive power, all those consisting of a series of operations dependent on one another, and to which much manual labour has to be applied, wind cannot be used. It can only serve for operations requiring little manual labour, in which the

power and the rate may increase or diminish, or even stop, without inconvenience. Such are tanning, oil, flour, and sawing mills, and, above all, irrigation, draining, and trenching—this we intend to study.

Different Systems of Wind Motors.

Windmills, the origin of which is very remote according to historians, who trace them back to Oriental nations, were much more used for all kinds of operations formerly than nowadays. The facility of transit and competition with steam-power have reduced their use to instances where they are really economical. Finally, their immovable nature and great size, when a certain power has to be obtained, prevent their use for farm works other than those for which they are specially erected. It is to be assumed that the portability of Lucet's motor will satisfy many requirements.

Wind motors may be divided into three classes :—

1. *Motors with horizontal or slightly inclined axis:*
   Ordinary windmills, with slightly concave blades ;
   Dutch windmills, with plane blades ;
   Berthon, Durand, Bellon windmills ;
   American windmills, with plane blades ;
   Lucet's motor, with parabolic blades.
2. *Motors with vertical axis:*
   Robinson's Windmill ;
   Panemones, &c.
3. *Atmospheric turbines.*

The description of the principal types of wind motors may be found in almost all works on industrial or agricultural engineering ; it is therefore easy to choose amongst them that which will apply best to the class of work required. Therefore, we will only study Lucet's motor, which is actually in use at the inventor's property at Conques, near Carcassonne. Its novel arrangements and restricted dimensions for so strong a motive power deserve special attention.

Lucet's Motor.

The motor requires no foundation or anchoring, for it is portable. It could even be called a locomotive if its rate of travelling allowed such a comparison to be made. It is astonishing to see this machine, heavy enough to resist the traction of the plough, hauling itself on its cable simply by the action of the wind, travelling slowly but surely over ploughed land, roads, or bridges.

Truck.—The truck is made of four large oak beams of 12 × 12 inches section, AA′ and BB′, mortised together so as to form a frame 13ft. 9in. × 18 feet. This frame rests on two strong girders CC′ made of ashwood, under which iron axles, 11 feet long, $2\frac{3}{4} \times 2\frac{3}{4}$ inches section, are bolted. Four cast-iron wheels DD′, 20 inches in diameter, are

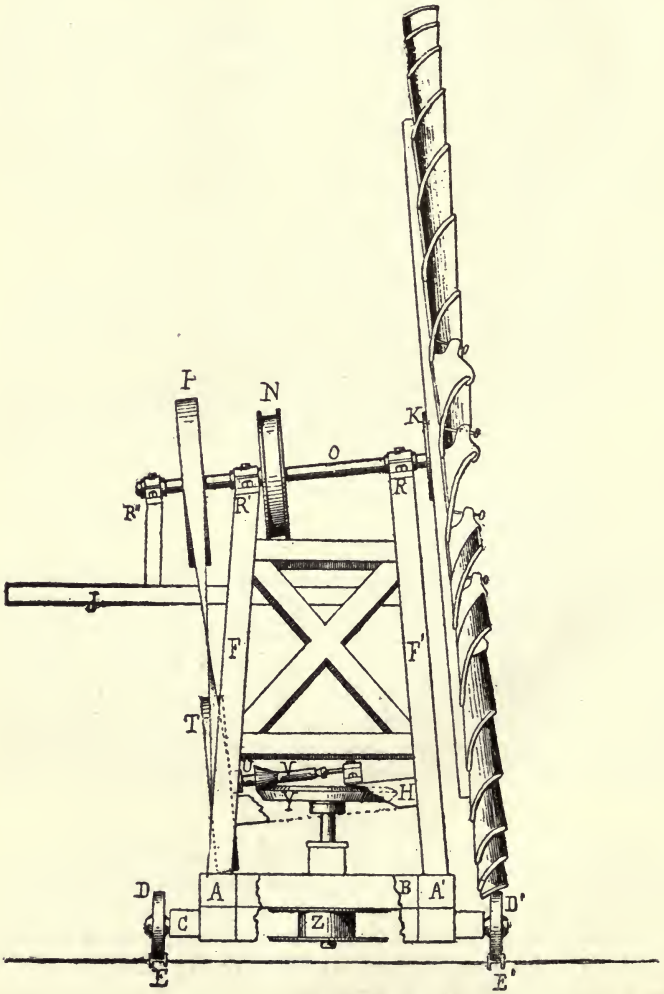


Fig. 97.—Lucet's Motor. Side Elevation.

attached to the axles, which are fixed in such a way that the four points of support (that is to say, where the wheels touch the ground) form a rectangle of 9ft. 10in. × 14 feet. The wheels are made so that their wide rim exactly fits between the flanges of rolled joist girders ($5\frac{1}{2}$ inches) EE′ (Fig. 97). Each of these girders weighs 220 lbs. They are, therefore, easily managed by two men.

Framework.—A rolled joist girder Q, 21 inches wide, is fixed under the centre of the truck; the shaft of the winding drum revolves in its centre. Four oak beams, 8 × 8 inches section F F′ and G G′, are mortised on the frame on a bevel, each pair joining at the top, and being each mortised

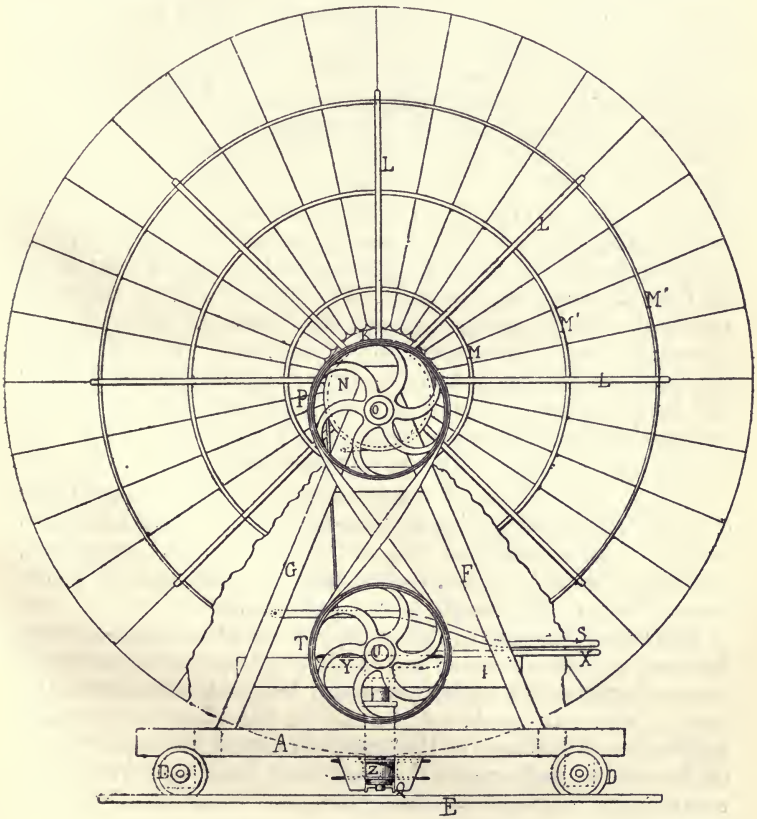


Fig. 98.—Lucet's Motor. Front Elevation.

in a solid wood block so as to form two isosceles triangles, the front one being rather higher than that at the rear. Braces and cross-beam are mortised to the four uprights to secure the necessary rigidity.

Other braces, HH′, II′ (Figs. 97 and 98), contribute to the strength of the structure, and at the same time serve to carry different collars and bearings; finally a beam J projects horizontally to a distance of 4ft. 10in. at the rear, so as to receive a prop or stay in case the wind is too strong, or, in any case, to protect the mechanism should the machine be blown over. Up to the present this has not been much required.

The frame of the Windmill.—A cast-iron plate K, 3ft. 3in. in diameter, and $\frac{4}{10}$ inch in thickness, is fixed on the main shaft by a brace and cotter. On the front part of this plate are eight lodgments, to receive eight arms L, $2\frac{3}{10} \times 1\frac{1}{2}$ inches section near the centre, and $2\frac{3}{10} \times \frac{4}{10}$ inches at the circumference. They are fixed in the lodgments by iron braces, bolted at the rear of the plate K. Three rings are braced to these arms M M′ M″, made of angle-iron riveted on flat iron. The first ring M (Fig. 99) forms a cylinder concentric to the shaft O, 6ft. 6in. in diameter, and $5\frac{1}{2}$ inches in height, provided with 32 openings to receive the vanes, the second ring M′ is 13 feet in diameter, the third M″ 19ft. 8in. They are both provided with 32 large notches, the curve of which corresponds to that of the vane which it supports. Fig. 99 shows the shape of these notches. The vanes are secured on the ring M″ by means of an iron pin *ab*, with a handle at *b*, and threaded at *a*, screwing in a brace *c*, by means of which the vane is compressed on the curvature of the notch.

Vanes.—The frame above described carries 32 vanes (four on each arm), made of pine-boards $\frac{3}{10}$ inch thick, 6 inches wide at the centre, and $32\frac{1}{2}$ inches wide at the periphery, forming a vane 11ft. 5in. in length, the small end of which is rounded to help the placing in position.

The vanes, instead of being plane as in other wind-motors, form an helicoidal curve, and as the mill revolves, the wind presses against the surface, less and less inclined towards the centre, where it is almost normal to the plane of the mill. In this way the shock of the wind is reduced in the first part of the curve, and gradually loses its speed to escape in the centre, after having transmitted to the motor all its motive energy.

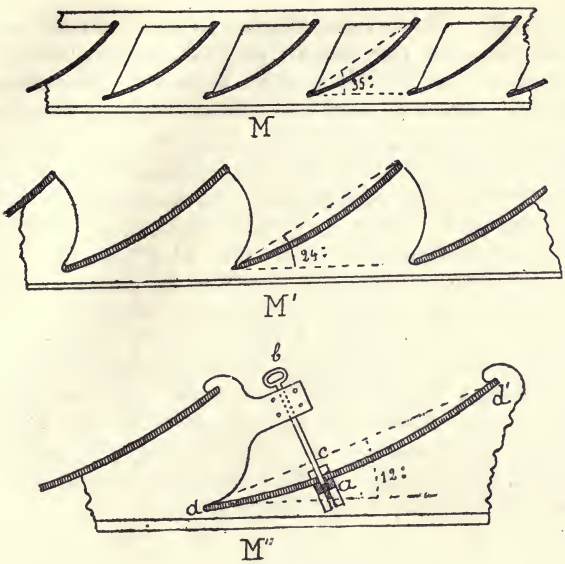


Fig. 99.

As all parts of the vanes do not revolve at the same speed, the chord of the parabolic segment of the section forms an angle of 32° towards the centre, and 12° only towards the periphery, with the plane perpendicular to the axis of the motor.

The curve of the vanes is secured by four pieces of ash-wood $\frac{4}{10} \times 1\frac{1}{2}$ inch section, drawn in the required curve, and nailed under each vane at distances of 3ft. 3in. apart. The part of the vane resting on the circles M M′ M″ is faced with zinc.

The motor is, therefore, a regular polygon, with 32 sides, and a diameter of 26ft. 3in. If the vanes are projected on a plane perpendicular to the axis they overlap each other to the extent of $\frac{4}{10}$ inch only, and in the centre there will be a circular opening 8 inches in diameter. The vanes have also lengthwise a curvature of $1\frac{1}{2}$ inch to utilize the centrifugal force developed by the rotary movement.

The mode of attachment of the vanes allows the sailing area to be regulated according to the strength of the wind, in the ratio 1:16, by removing some of the vanes two by two on the same diameter, so as not to disturb the equilibrium of

the machine. Each vane weighs from 11 to 13 lbs.; one man may fix four per minute, and remove six in the same time, that is to say, that eight minutes are sufficient to fasten all the vanes on, and five minutes only to remove them.

Mechanism.—A shaft O (Fig. 97), $4\frac{3}{10}$ inches in diameter, inclined 5° 40′ from the horizontal, carries the circle of vanes and a pulley P made of ashwood, and revolves through three collars, R R′ R″. The collars R R′ are bolted right down to the foundation iron beam Q, by four long iron rods.

The circular iron plate N, 3ft. 6in. in diameter, is keyed on the shaft O by a conical adjustment, serving as an abutment against the collar R′, forming a very strong and rigid assemblage able to sustain the enormous strain during stoppages. Round the plate N is a steel band, provided with wooden brakes faced with leather, fixed by one end to the frame, and by the other to a lever S (Fig. 98), multiplying the weight of the man by 8, and what is more, the brake acts in the direction of the rotation.

Transmission.—A pulley P, 4ft. 9in. in diameter, keyed on the shaft O, transmits the rotary motion by a crossed belt to another pulley T of the same diameter. The shaft U of the pulley T is parallel to the shaft O, and carries a steel bevel-pinion V, of 7 inches diameter, provided with ten teeth which can be thrown in or out of gear by a lever X with a large cog-wheel Y, keyed on the shaft of the drum Z.

Drum.—The bevel cog-wheel Y is 4ft. 8in. in diameter and carries 44 teeth. The drum is $17\frac{1}{2}$ inches in diameter, 3ft. 3in. with the flanges.

The cable is $\frac{9}{16}$ inch in diameter, 220 to 270 yards in length.

Working.—During the night the vanes of the lower part of the wheel only are left on to prevent it from revolving. Therefore, in the morning four minutes are required to place the sixteen vanes in position again, then the brake being on, the pinion V is thrown into gear with the cog-wheel Y and the brake released; the wheel then starts turning, revolving the drum, which winds the cable at a speed varying between 6 to 14 inches per second, according to the power of the wind. A cable-carrier is placed on the ground 10 feet from the machine, and level with the middle of the drum; the machine goes on working in this manner while the plough is hauled with great smoothness and steadiness. When the plough is close enough to the motor, the speed is decreased by means

of the brake, then the ploughman places a forecarriage in front of the plough, made of two wheels and an axle bent at a right-angle, and, by a kind of tilting movement, as the plough progresses it is lifted out of the furrow (Figs. 20 and 21, pages 40 and 41). Finally, when the plough is completely out of the furrow the drum is thrown out of gear and the motor stopped; the ploughman takes it back with a horse, while the men at the motor shift it sideways a distance equal to the width of the furrow. This is done with an ordinary crowbar if the land is level, and with a screw-jack if it is rising; twelve furrows are opened in this manner, when another pair of rails are placed in front of the wind-mill carriage. This operation is repeated every twelve furrows. Two men are, therefore, necessary for the management of the plant, one for the plough and the horse, and one for the wind-mill. The addition of a second cable and drum revolving at a greater speed to haul the plough back would complicate the machine uselessly, although machines are made with the extra attachments.

The headlands can be easily ploughed, as the cable can haul in any direction, but, in this case, wedges must be placed under the wheels to enable the machine to resist the side strain.

Shifting the motor from one block to another.—When the ploughing of a block is finished, it is easy to shift the motor to another by using it as a self-moving motor. In this case the plough is hauled by the horse in the desired direction, and placed as if about to open a furrow; the drum is then thrown into gear, and, when the cable starts to wind, as the wheels are not wedged, the latter, offering the least resistance, travels towards the plough at a speed of 16 inches per second. It is not necessary to attain a greater speed, as the rails have to be displaced every 20 feet.

Stability.—When the motor hauls the plough in a direction perpendicular to that of the rails, its weight (5 tons 18 cwt. to 6 tons 17 cwt.) suffices to secure the required stability, as the flanges of the rolled joist girders serve, at the same time, as anchors in the ground and blocks against the wheels; when the direction becomes oblique it suffices to block two of the wheels with pegs. It results from calculations made on this machine, that if we assume the motor with all its vanes, and arrested by the brake (the most unfavorable case), the pressure of the wind should attain 85 lbs. per square yard, that is to say, a rate of 59 feet per

second ; assuming the vanes normal to the direction of the wind, Hutton's formula, used for inclined surfaces, gives a value rather higher—62 feet to 65 feet, that is to say, a gale.

Orientation.—To change the orientation of the motor, the extremity of the iron girder Q is lifted by a screw-jack, and, under the centre of the beam, two solid wooden blocks with a pivot are placed ; four axle arms are placed on the main frame A in a radiating direction, four supplementary wheels are fixed on them, transforming the frame into a kind of turn-table; the orientation is then done by hand as in the case of locomotive engines.

Work.—We give below the figures obtained by the inventor when trenching his property. We are at present unable to authenticate them, but intend to verify them with Prony's mechanical brake. When the rate of the wind does not exceed 20 feet per second all the vanes are left on, and the rate of the cable varies between 4·6 to 7·8 inches per second, the area ploughed is 72 to 120 poles per day, to a depth of 19½ to 24 inches. When the rate of the wind increases, the vanes are gradually removed, so that twelve to fourteen only remain on when the rate of the wind reaches 26 feet, eight to ten when it reaches 32 feet, so that the power obtained does not exceed 7 to 8 B.H.P.

Observations.—The general disposition of the framework, and of the vanes, allow an easy motion of the wheel, although the power obtained is fairly great. This is probably due to the curvature of the vanes, the mechanical yield of which seems to be greater than that of most wind-mills. If we consider the formula generally adopted to represent the motive power of wind-motors :—

$$T = \frac{S \times p \times v^3}{2\,g},$$

T, being the theoretical work the wind is capable of giving ;
S, the area of the vanes ;
p, the weight of a cubic metre of air, *i.e.*, 1·293 kilos.;
v, the rate of wind in metres per second ;
g, the acceleration due to gravitation, *i.e.*, 9·808 metres.

According to the experiments of Smeaton and Coulomb, the mechanical yield would be, for ordinary wind-mills, 45 per cent.; for American wind-mills, 57 per cent. We may admit a yield of 70 per cent. for Lucet's motor on account of the

curvature of the vanes, and the great area of the wheel (59 square yards), and we know that the pressure of the wind increases more rapidly than the surface ; however, further scientific experiments are required to fix the mechanical yield of this machine. The above formula would give for a rate of wind of 4 metres (13ft. 1½in.) per second :—

$$T = \frac{3{\cdot}14\ 16 \times 4^2 \times 1{\cdot}293 \times 4^3 \times 70}{2 \times 9{\cdot}808 \times 100} = 148{\cdot}45,$$

that is to say, 148 kilos (325 lbs.) per second, almost 2 H.P. The following table, calculated by the same formula, shows for different rates of wind the probable power of Lucet's motor, and the corresponding number of fans :—

Rate of the wind in metres per second. (1 metre = 3ft. 3in.)	Available Power.		Number of Vanes.
	Kilogramme metres per second.	H. P.	
3	62·62	0·84	32
4	148·45	1·98	32
4·50	211·36	2·82	32
5	289·94	3·87	32
6	501·01	6·68	32
7	497·25	6·63	20
8	519·57	6·92	14
9	528·55	7·04	10
10	579·87	7·74	8
11	578·86	7·71	6
12	501·01	6·68	4
13	636·99	8·89	4
14	379·80	5·30	2
15	489·27	6·52	2
16	593·79	7·91	2

The management of the motor and its displacement have been well studied, but its orientation is tedious and very defective, as, in the case of the wind not blowing perpendicular to the direction of the headland, that headland becomes triangular, and, in certain cases, might attain half the area of a square block if the wind blows diagonally. This defect might easily be remedied by fixing four rollers under the framework, travelling on a circular rail, carried by four rollers travelling on rolled joist girders in a similar manner to a turn-table. Finally, although the machine is only built for the purpose of trenching or subsoiling, its

inventor has constructed it so that it may be dismounted in three pieces for transit, and provided it with a pulley, allowing the power to be transmitted by belting to any machine.

The motor is working near Carcassonne on an average five days a week, and meteorological observations enable us to foresee that the number of days could be increased during December, January, February, March, and especially April; the winds are less frequent during the rest of the year.

APPENDIX.

COMPARATIVE METRIC AND BRITISH LAND MEASURES.

—	Exactly.	Roughly.
Hectare	2·471 acres ...	Nearly two and a half acres.
Are	3·954 poles ...	Nearly four poles or $\frac{1}{40}$ acre.
Centiare (square metre)	1·196 sq. yds.	Nearly one and one-fifth sq. yds.

HECTARES = ACRES.

Hectares =	Acres	Hectares =	Acres	Hectares =	Acres
1 =	$2\frac{1}{2}$	7 =	$17\frac{1}{4}$	40 =	99
2 =	5	8 =	$19\frac{3}{4}$	50 =	$123\frac{1}{2}$
3 =	$7\frac{1}{2}$	9 =	$22\frac{1}{4}$	60 =	$148\frac{1}{4}$
4 =	10	10 =	$24\frac{3}{4}$	70 =	173
5 =	$12\frac{1}{3}$	20 =	$49\frac{1}{2}$	80 =	$197\frac{3}{4}$
6 =	$14\frac{3}{4}$	30 =	74	100 =	247

ACRES = HECTARES.

Acres =	Hectares	Acres =	Hectares	Acres =	Hectares
1 =	0·40	7 =	2·83	40 =	16·19
2 =	0·81	8 =	3·24	50 =	20·23
3 =	1·21	9 =	3·64	60 =	24·28
4 =	1·62	10 =	4·05	70 =	28·33
5 =	2·02	20 =	8·09	80 =	32·37
6 =	2·43	30 =	12·14	100 =	40·47

BRITISH LAND MEASURES.

1 Acre = 4 Roods = 160 Poles = 4,840 Square Yards.
1 Rood = 40 " = 1,210 "
1 Pole = $30\frac{1}{4}$ "

LAND MEASURES USED IN DIFFERENT COUNTRIES.

—	—	Contents of a Single Measure of each Sort.		Number of each equal to 10 English Acres.
		English Square Yards	French Acres.	
England and Australia	Acre	4840	40·466	10·000
Scotland ...	Acre	6150	51·419	7·869
Ireland ...	Acre	7840	65·549	6·173
France ...	Hectare	11960	100·000	4·046
Berlin	Great Morgen ...	6786	56·736	7·132
	Little Morgen ...	3054	25·534	15·848
Prussia ...	Morgen	3053	25·526	15·853
Saxony ...	Acre	6590	55·098	7·344
Hamburg	Scheffel of Corn Land	5022	41·984	9·637
	Morgen	11545	96·525	4·192
Hanover ...	Morgen	3100	25·918	15·613
Nuremberg	Corn Land Morgen	5654	47·272	8·560
	Meadow Morgen ...	2544	21·270	19·025
Rhineland ...	Morgen	10185	85·158	4·752
Dantzic ...	Morgen	6650	55·642	7·278
Geneva ...	Arpent	6179	51·661	7·833
Amsterdam ...	Morgen	9722	81·286	4·978
Netherlands ...	Vierkantebunder ...	119·6	1·000	406·722
Naples ...	Moggia	3998	33·426	12·106
Spain ...	Fanegada ...	5500	45·984	8·800
Portugal ...	Geira	6970	58·275	6·944
Sweden ...	Tunneland ...	5900	49·329	8·203
Switzerland ...	Faux	7855	65·674	6·161
Tuscany ...	Quadrato ...	4074	34·062	11·880

ILLUSTRATIONS.

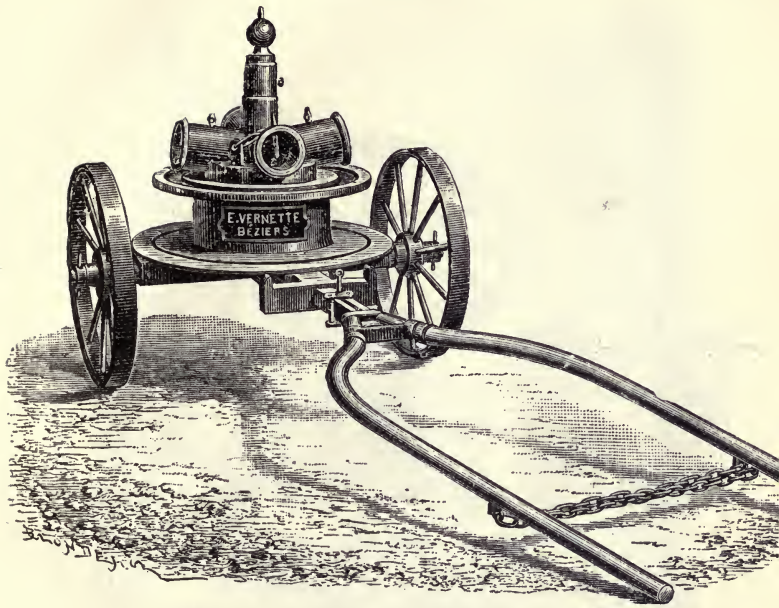


Fig. 100.—Vernette's Small Capstan, mounted on wheels.

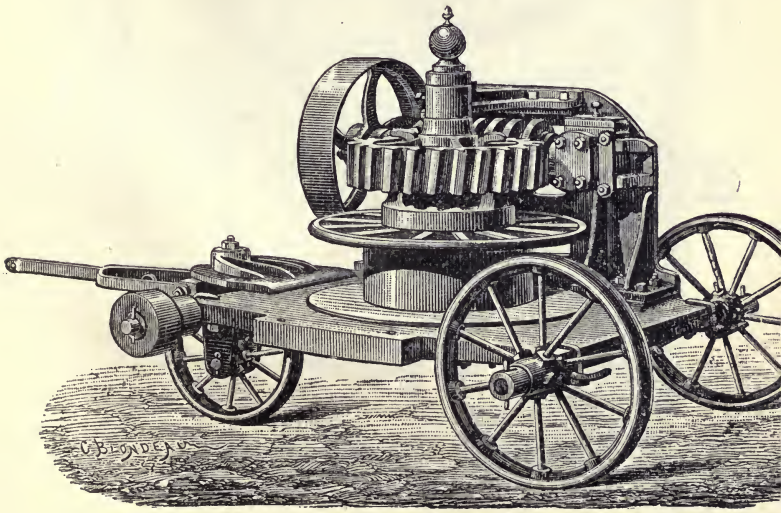


Fig. 101.—Vernette's Steam Winding Drum, with endless screw.

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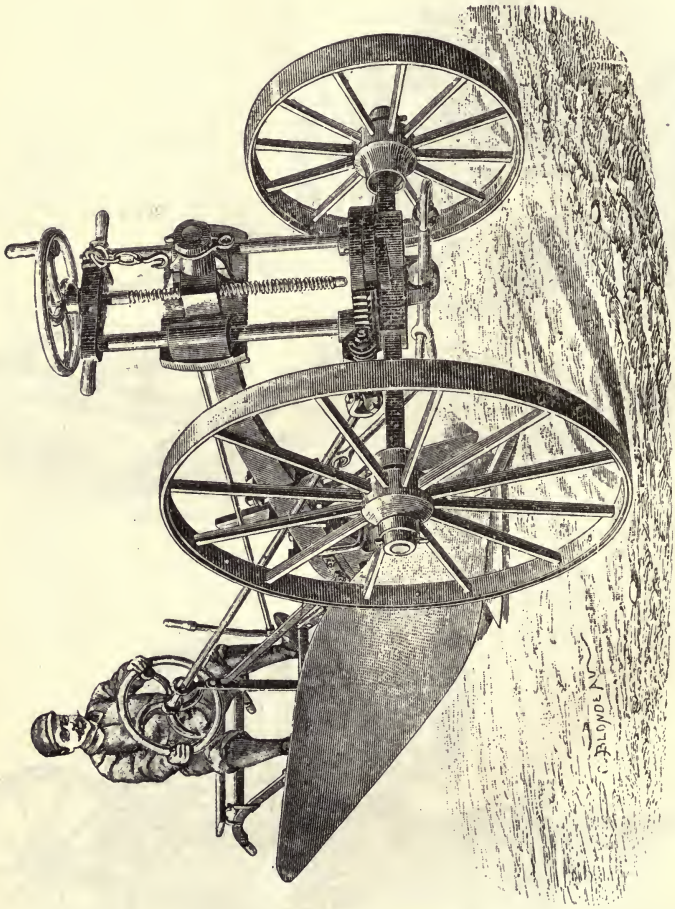

Fig. 102.—Vernette's Steam Plough, with seat.

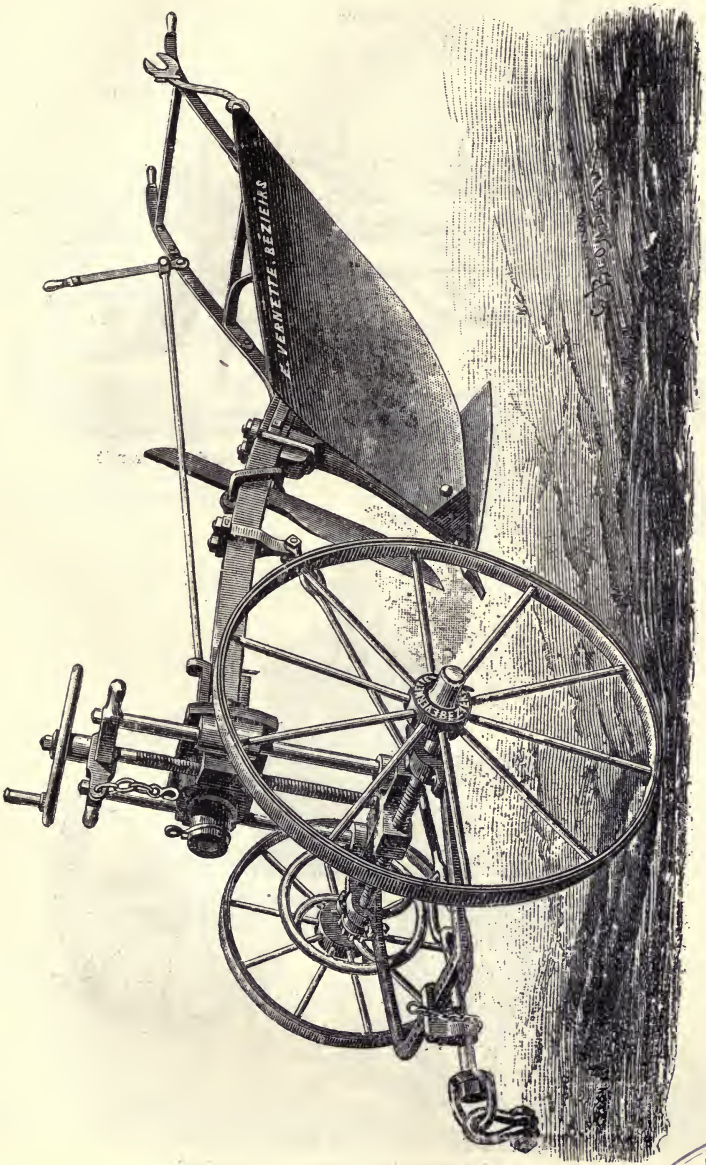

Fig. 103.—Vernette's Large Trenching Plough.

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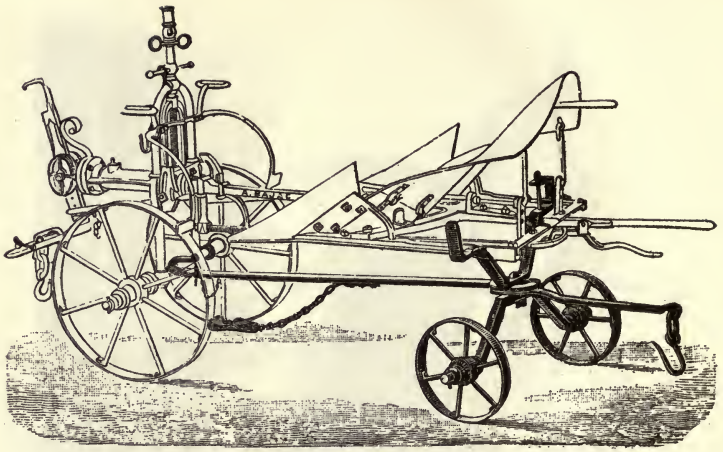

Fig. 104.—Turn-Wrest Plough, mounted on patent carrier for transit.

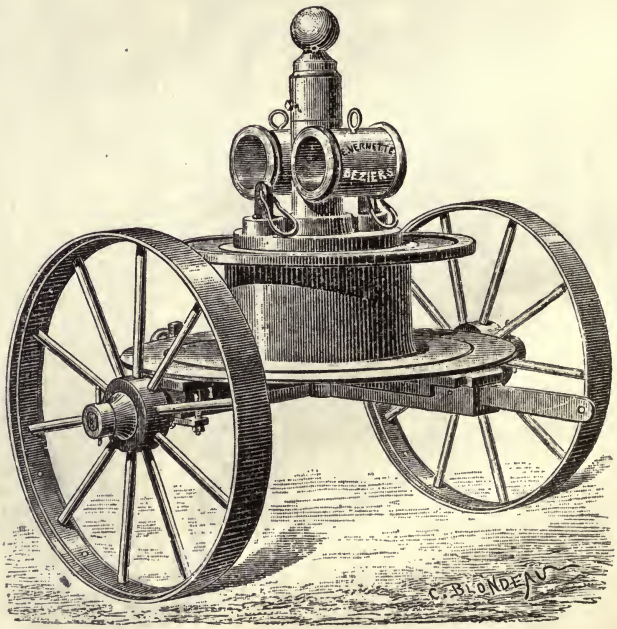

Fig. 105.—Vernette's Capstan. Pattern 1892.

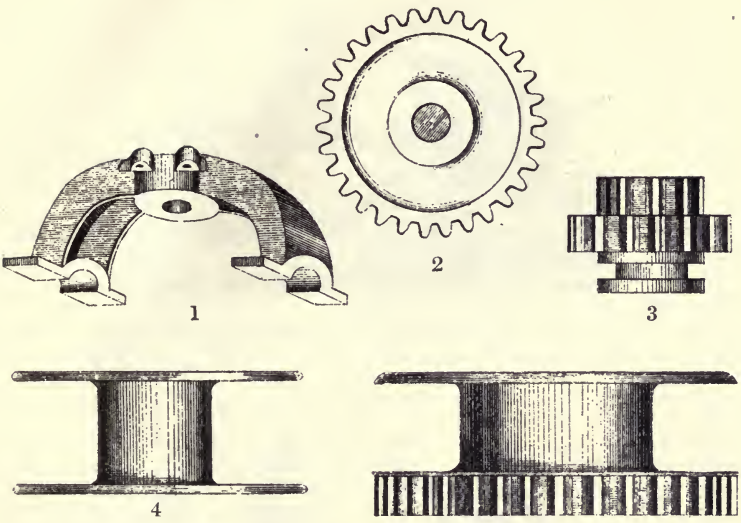

Fig. 106.—Guyot's Horse-Gin. 1. Bridge; 2. Large Cog-Wheel; 3. Coupling Clutch; 4. Small Drum; 5. Large Drum.

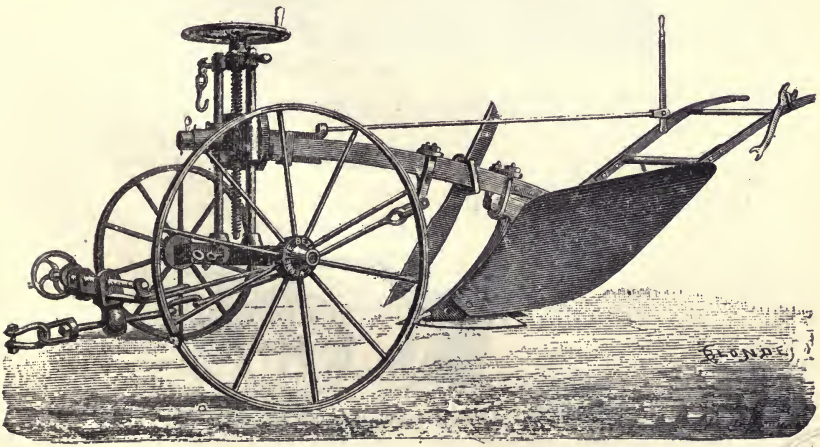

Fig. 107.—Vernette's Trenching Plough. Pattern 1891.

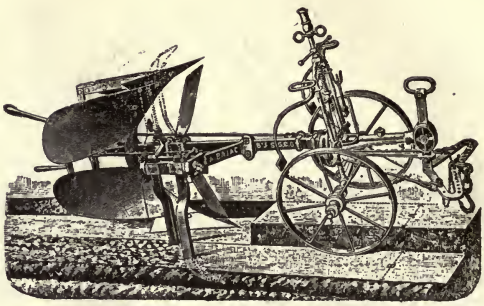

Fig. 108.—Bajac's Turn-Wrest Plough, with subsoiling tines on the side.

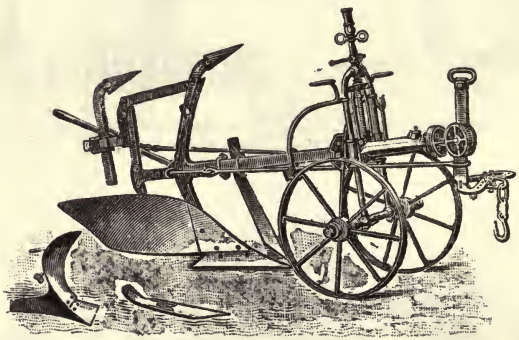

Fig. 109.—Bajac's Turn-Wrest Plough, transformed for subsoiling.

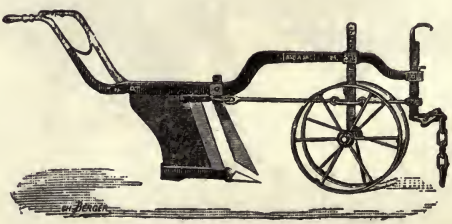

Fig. 110.—Bajac's Subsoiler, used to cut roots.

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